

THE ROLE OF MODERN BIOTECH SYSTEMS OF
INNOVATION IN MARKET CREATION: A
COMPARATIVE STUDY BETWEEN MEXICO AND
SPAIN

A Dissertation

Presented to the Faculty of the Graduate School
of Cornell University

in Partial Fulfillment of the Requirements for the Degree of
Doctor of Philosophy

by

Rafael Escalona Reynoso

August 2012

© 2012 Rafael Escalona Reynoso

ALL RIGHTS RESERVED

THE ROLE OF MODERN BIOTECH SYSTEMS OF INNOVATION IN
MARKET CREATION: A COMPARATIVE STUDY BETWEEN MEXICO AND
SPAIN

Rafael Escalona Reynoso, Ph.D.

Cornell University 2012

This research puts forward an alternative methodology for the study of knowledge accumulation and innovation production in modern biotech. It presents the results of a series of thought experiments designed to measure and contrast the effects of structural differences in the performance of Mexico and Spain's modern biotech innovation systems. Borrowing concepts from neoclassical, endogenous growth, and regional systems of innovation theories and supplementing these with empirical data analysis findings, this research introduces a systems model that helps better understand how technological changes in this sector are being shaped by the interaction of multiple factors and agents, including the government.

Findings suggest that Mexico's modern bio-technology system (MBTS) as modeled is, in the short term, more efficient than that modeled for Spain, especially in the creation of new marketable products and services deriving from this technology. Further analysis, however, determines that the system is deprived from this advantage in the later mid and long terms and also becomes considerably less efficient than that modeled for Spain in various other areas. When the model for Mexico's system is supplemented with specific institutional and regulatory elements—most which are present in Spain's MBTS model—its performance improves above that of its current state and beyond that of Spain in particular key areas, including market creation.

The conclusions obtained in this study help both presenting modern biotech

from a Systems of Innovation perspective and producing a concise list of recommendations that can serve as reference for the design of policies to assist in revamping the current MBTS operating in Mexico.

BIOGRAPHICAL SKETCH

Rafael Escalona Reynoso is a Ph.D. candidate in City and Regional Planning with concentrations in Regional Science, Social Studies of Science and Technology, Risk Analysis, Communication, and Policy at Cornell University. He received a Master of Public Administration degree from the Cornell Institute for Public Affairs in 2005 and a Bachelor in Economics from the Universidad Panamericana in Mexico City in 1999.

He worked as research assistant at the Center for Demographic, Urban and Environmental Studies of El Colegio de Mexico in 1998, as project leader within the 2000 president-elect transition team, and as part of the congressional advisory committee that helped develop the Mexican Biosafety of Genetically Modified Organisms Law and the Mexican Federal Commission for Sanitary Risks before coming to Cornell.

His current research focuses on the limits of intellectual property rights (IPRs), policy implications of innovation in areas of the New Life Sciences, as well as on the creation of markets for new technologies.

The moment I finished writing this dissertation, my computer was playing the song “She’s like a Rainbow” by the Rolling Stones. I could not agree more. This dissertation is dedicated to Lisa Pasternak, Ara Reynoso Mena, and Rafael Escalona Flores.

ACKNOWLEDGMENTS

Thank you Mom and Dad for your love, support, and for never doubting that this was attainable. Thank you, my dearest Lisa, for being the light of my life and for preserving your love and patience. You three were my pillars during this adventure.

Thank you Kieran, John, David, and Stephen for passing along your knowledge and for helping me accomplish this project. Thank you, Jeannine, for giving me the opportunity to teach during these years. Thank you, Mayte, for being there during the first stage of this voyage.

Special thanks to Linda and Lisa Pasternak for proofreading this extensive document.

This project would not have been possible without the sponsorship of the Mexican Council for Science and Technology, whose scholarship #187551 funded most of my studies. The Government of Tlaxcala and Mexico's Public Education Secretariat, I am also grateful for your assistance. Thank you again, Dad, for helping me cover what was not anticipated.

I also want to dedicate this document to my faithful writing companion Kirby Cat; you certainly eased those days when writer's block was the name of the game. Oh... and thank you, Jimmy Fallon, for inspiring me to use the "Thank You Notes" format...

TABLE OF CONTENTS

Biographical Sketch	iii
Dedication	iv
Acknowledgments	v
Table of Contents	vi
List of Tables	viii
List of Figures	x
List of Acronyms and Abbreviations	xi
Preface	xix
INTRODUCTION	1
1 MODERN BIOTECH SYSTEMS OF INNOVATION	8
1.1 Defining Modern Biotech as a Set of Technological Systems	8
1.2 General Challenges and the Systems of Innovation	9
1.3 General Challenges and their Effect on Modern Biotech	13
1.4 New Policies and the Systems of Innovation Approach	15
1.5 The Economics of the Systems Approach	17
2 NETWORKS AND INSTITUTIONS OF TWO SYSTEMS OF INNOVATION	19
2.1 Two Countries, Two Systems, One Technology	19
2.2 Two Systems of Innovation: The Cases of Mexico and Spain.	20
2.2.1 Institutional Frameworks	23
2.2.2 Mexico	24
2.2.3 Spain	47
2.2.4 Policy and Regulatory Frameworks	78
2.2.5 Mexico	78
2.2.6 Spain	88
2.2.7 Contrasts and Findings	104
3 DYNAMICS OF TWO MODERN BIOTECH SYSTEMS OF INNOVATION	116
3.1 Modeling Spain and Mexico's Modern Biotech Systems	116
3.1.1 Discussion of Methods I: Overview	118
3.1.2 Discussion of Methods II: General Model's Structure and Key Components	127
3.2 System Performance Assessment	240
3.2.1 Experiment Design	240
3.3 Results	247
3.3.1 General (or Non-Parametric) Model	247
3.3.2 Adapted Model for Spain	265
3.3.3 Adapted Model for Mexico	276
3.3.4 Mexico Adapted to Best Treatment	291

4	POLICY RECOMMENDATIONS, RESEARCH PROSPECTS, AND THEORETICAL CONSIDERATIONS	302
4.1	Lessons Learned	302
4.2	Policy Recommendations and Research Prospects	304
4.3	Theoretical Considerations	316
4.4	Final Thoughts	319
A	Questionnaire	321
B	Appendix: Model's Equation (Mexico)	324
	Bibliography	367

LIST OF TABLES

2.1	Number of Actors by Country and Sector	22
2.2	Actors by Country, Sector and Code	23
2.3	Frameworks and Key System Components	24
2.4	Key Elements in Spain and Mexico’s MBTS	109
2.4	. . . . .	110
2.4	. . . . .	111
2.4	. . . . .	112
2.4	. . . . .	113
2.4	. . . . .	114
2.4	. . . . .	115
3.1	Selected Treatment Subset	242
3.2	Effect of Selected Treatments on “New Development” Re- sponse Variable: Equation Parameters	244
3.2	. . . . .	245
3.2	. . . . .	246
3.3	Effect of Selected Treatments on “New Development” Re- sponse Variable: Response Per Term	248
3.3	. . . . .	249
3.4	Effect of Selected Treatments on “New Development” Re- sponse Variable: Rank and Change	251
3.4	. . . . .	252
3.5	Effect of Selected Treatments on “New Development” Re- sponse Variable: Percentage Change per Period and Compari- son to Neutral Treatment	256
3.5	. . . . .	257
3.5	. . . . .	258
3.5	. . . . .	259
3.6	Response to Treatment: Overall Rank	263
3.7	Adapted Model for Spain: Parameters for Selected Variables	268
3.7	. . . . .	269
3.8	Adapted Model for Spain: Response from Selected Variables	271
3.8	. . . . .	272
3.9	Adapted Model for Mexico: Parameters for Selected Variables	279
3.9	. . . . .	280
3.10	Adapted Model for Mexico: Response from Selected Variables	281
3.10	. . . . .	282
3.11	Contrasting Mexico Current and Spain	290
3.12	Adapted Model for Mexico: Parameters for Selected Variables to “All On-IPRL-IPRB” Treatment	293
3.12	. . . . .	294

3.13	Adapted Model for Mexico: Response from Selected Variables to “All On-IPRL-IPRB” Treatment	296
3.13	. . . . .	297
3.14	Mexico: Contrasting Current and Best Treatment	300
3.15	Mexico: Contrasting Best with Spain	301

LIST OF FIGURES

3.1	Map Layer: Modern Biotech Systems Model	130
3.2	Research Module Subsystem	134
3.3	Research's Module Stochastic Component	136
3.4	Development Module Subsystem	139
3.5	Development's Module Stochastic Component	141
3.6	Development Module: In Market	142
3.7	Innovation Module: Information Management Stocks	147
3.8	Clustering's Information Spillover Effect	150
3.9	Information Transferring Process	153
3.10	Biosafety Process	160
3.11	Health Inspection Process	167
3.12	R&D Infrastructure Mechanism	173
3.13	Financial Resources to Research	177
3.14	Financial Resources to Development	184
3.15	Financial Resources to Government	189
3.16	R&D Investment, Savings and Spendings	191
3.17	Risk-Free Investment and Venture Capital to R&D	198
3.18	Venture Capital Investment Decision Mechanism	203
3.19	Venture Capital Funds and Debt Balance Stock	207
3.20	International Venture Capital Mechanism	211
3.21	Resources for Basic Research Infrastructure	214
3.22	Available Human Capital for Biotech R&D	215
3.23	Research-to-Development Labor Mobility Process	220
3.24	Genetic Resources Bio-Prospecting Process	222
3.25	Natural Resources Balance Process	226
3.26	IPR Policy Process	230
3.27	Biosafety Policy Process	233
3.28	Health Safety Policy Process	235
3.29	R&D Promotion Policy Process	238
3.30	Spain: Probability Plot for Patented Knowledge	287
3.31	Mexico: Probability Plot for Patented Knowledge	289

LIST OF ACRONYMS AND ABBREVIATIONS

AGEMED	Spanish Medicine and Sanitary Products Agency
AMC	Mexican Academy of Sciences
ANUIES	Mexico's National Association of Universities and Higher Education Institutions
ASEBIO	Spanish Association of Bio-enterprises
BIOANCES	Spanish Association for European Business and Innovation Centers
BioCat	Bioregion of Catalonia
BIOMADRID	Madrid's Regional Association of Biotechnology
CAFS	Catalan Agency of Food Safety
CAIT	Supporting Innovation Center
CBG	IPN's Genomic Biotech Center
CDTI	Spain's Centre for the Development of Industrial Technology
CENIT	Spain's National Strategic Technical Research Consortiums Program
CGIAR	Consultative Group on International Agricultural Research
CIAD	Mexico's Food and Development Research Center
CIATEJ	Technology and Design Support Research Center of the State of Jalisco

CIBIOGEM	Mexico's Inter-secretarial Commission on Biosafety of Genetically Modified Organisms
CIBNOR	Mexico's Northwestern Biological Research Center
CICESE	Scientific Research and Higher Education Center of Ensenada
CICY	Scientific Research Center of Yucatan
CIEMAT	Spain's Environmental and Technological Research Center
CIMMYT	International Maize and Wheat Improvement Center
CINVESTAV	IPN's Advanced Research and Studies Center
CIOMG	Spain's Inter-ministerial Council for Genetically Modified Organisms
CMDRS	Mexican Council for Sustainable Rural Development
CMR	Centre for Regenerative Medicine
CNBio	Mexico's National Bioethics Commission
COFEPRIS	Mexico's Federal Commission for the Protection against Sanitary Risk
COFUPRO	PRODUCE National Coordination Office
CONABIO	Mexico's National Commission for the Knowledge and Use of Biodiversity
CONACyT	Mexico's National Council for Science and Technology
CRG	Spain's Centre for Genomic Regulation

CSIC	Spain's National Research Council
CT	Technological Center
DNA	Deoxyribonucleic Acid
EBF	European Federation of Biotechnology
EC	European Community
ECPVO	EC Plant Variety Office
EEA	European Environment Agency
EFSA	European Food and Safety Agency
EMA	European Medicines Agency
ENCyT	Spain's National Science and Technology Strategy
EPO	European Patents Office
ERC	European Research Council
EU	European Union
EUFTA	European Free Trade Agreement
EUOJ	EU's Official Journal
EUROPABIO	European Association for Bioindustries
FIRA	Mexico's Federal Trust Funds for Rural Development
FIRCO	Mexico's Federal Trust Fund for Shared Risk
FOCIT	Mexico's Federal Rural Capitalization and Investment Fund

FONAES	Mexico's National Support Fund for Solidarity Enterprises
FONCICyT	Mexico's International Research and Development Cooperation Fund
FP7	EU's 7th Research Framework Programme
GDP	Gross Domestic Product
GM	Genetically Modified
GMO	Genetically Modified Organism
iBt-UNAM	UNAM's Biotechnology Institute
IICA	Inter-American Institute for Cooperation in Agriculture
IMI	European Innovative Medicine Initiative
IMPI	Mexican Industrial Property Institute
INE	National Ecology Institute
INECOL	Mexico's Ecology Institute
INEGI	Mexico's National Institute of Statistics and Geography
INEGI	Mexico's National Institute of Statistics and Geography
INIA	Spain's National Institute for Agrarian and Food Research and Technology
INIFAP	Mexico's National Fishery, Agriculture, and Livestock Research Institute
INMEGEN	Mexico's Genomic Medicine Institute

INS	Mexico's National Health Institutes
IPICYT	Potosinian Scientific Research Center
IPN	Mexico's National Polytechnic Institute
IPRs	Intellectual Property Rights
IT	Information Technologies
ITESM	Technological and Higher Education Institute of Monterrey
JTI	Joint Technology Initiatives
LBOGM	Mexico's Biosafety of Genetically Modified Organisms Law
LCyT	Mexico's Science and Technology Law
LGMO	Living Genetically Modified Organism
MBTS	Modern Bio-technological System
MEH	Spain's Ministry of Economics and Treasury
MI	Spain's Ministry of Interior
MICINN	Spain's Ministry of Science and Innovation
MITYC	Spain's Ministry of Industry, Tourism, and Commerce
MMA	Spain's Ministry of Environment, Agriculture and Fisheries
MSC	Spain's Ministry of Health and Social Policy
NABI	North American Biotechnology Initiative
NAFTA	North American Free Trade Agreement

NBC	Spain's National Biosafety Commission
NGO	Non-Governmental Organization
NLS	New Life Sciences
NSI	National Systems of Innovation
OAS	Organization of American States
OEPM	Spanish Patents and Trademarks Office
OTRI	Technology and Innovation Transfer Office
PCB	Barcelona Research Park
PND	Mexico's National Development Plan
PNI&D+i	Spain's National Scientific Research, Development, and Technological Innovation Plan
PRBB	Barcelona Biomedical Research Park
PRODUCE	Produce Foundations
PROFEPA	Mexico's Federal Environmental Protection Agency
PROFIT	European Scientific Research Promotion Program
R&D	Research and Development
R&D+1	Research and Development plus Innovation
RBR	Spain's Bioregions Network
rDNA	Recombinant DNA

RENIECyT	Mexico's National Scientific and Technological Industries and Institutions Network
RSI	Regional Systems of Innovation
S&T	Science and Technology
SAGARPA	Mexico's Health, Agriculture, Livestock, Mexico's Rural Development, Fisheries and Food Secretariat
SE	Mexico's Economy Secretariat
SEMARNAT	Mexico's Environment and Natural Resources Secretariat
SENASICA	National Service of Agro-alimentary Health, Safety, and Quality
SEP	Mexico's Public Education Secretariat
SHCP	Mexico's Finance and Public Credit Secretariat
SMBB	Mexican Biotechnology and Bioengineering Society
SME	Small and Medium Enterprise
SNI	Mexico's System of National Researchers
SNITT	Mexico's National Research and Technology Transfer System for the Sustainable Rural Development
SSM	Madrid's Sanitary Service
STIGS	Science, Technology, Innovation, and Growth Systems
STSP	Mexico's Science and Technology Special Program
TS	Technological System

UN	United Nations
UNAM	Mexico's National Autonomous University
UNEP	UN Environmental Program
USPTO	United States Patent and Trademark Office
VC	Venture Capital
WIPO	World Intellectual Property Organization
WTO	World Trade Organization
YIC	Young Innovative Company Status

PREFACE

In one of the most captivating scenes in movie history, the brilliance of director Roland Joffé depicts the moment when a Jesuit monk, astray from the path followed by his fellow missionaries, roams through the Amazon Jungle. Realizing he is being followed by local “savage” tribe hunters, unarmed and virtually helpless, he resolves to use the only object he carries; an oboe. While sitting on a stone in the middle of a creek below the jungle’s canopy he begins playing a pleasing musical piece. Allured by the novelty, tranquility, and harmony of the melody, the tribal hunters —still aiming bows and spears— come out of their jungle vantage points to congregate —in complete awe— around him. Moments later, an older and perhaps more prudent tribal hunter emerges from the jungle and, while vociferating in his dialect, walks up to where the monk is playing his instrument. Once close enough, he rips the oboe from the monk’s hands and turns towards the rest of the congregated tribe members, pointing his finger at them and raising his fist in the air to condemn their tolerance for the intruder. He then snaps the instrument in two and throws the broken pieces into the creek, exiting the scene as the rest of the hunters remain gathered around the stranger. Once gone, one of the tribal hunters collects the pieces of the broken instrument and tries —to no avail— to put them back together. After failing to fix the instrument, he hands the pieces to the monk, who simply nods back at him suggesting there is no way to fix it, let alone to keep playing the melody. As the scene closes, the camera captures the hunters —along with the missionary— walking downstream as a single group.

Beyond religious or cultural innuendos, the power of this scene rests on the successful way it captures art’s ability to transcend human language and understanding. The piece also points out the fact that art —like science— requires

both artifacts and performers for its expression, suggesting that the absence of either can curtail its creation and diffusion. Moreover, it displays how easily any of the processes associated to either —creation, diffusion, and expression— can fall hostage to ideologies or belief systems within particular social structures.

The way art expression is approached in this scene almost perfectly echoes the ways in which modern biotechnology has been approached since its inception in the early seventies; with both awe and fear. Although not all unjustified or scientifically invalid, many of the attitudes towards the possible consequences of the application of biotechnology have curtailed its full advancement, in much a similar way as the hunter leader curtailed the monk's performance when snapping and breaking the oboe in the previously described scene. Yet, at this time and age modern biotechnology still lacks a critical mass of bold explorers that can circumvent these attitudes and truly concentrate on the art—not the doubt— and become both performers and artifact creators. Furthermore, it yet needs to witness a rise in the number of leaders that can encourage these enterprising attitudes while reducing—in a genuine and prudent manner— fears and concerns.

These modern biotechnology pioneers appear to develop more easily in some environments than in others, helping to create sophisticated regional networks of both performers (specialized human capital with cutting-edge skills) and artifacts (like state-of-the-art instruments, laboratories and research centers). Through a comparative analysis exercise between the systems of innovation for modern biotechnology of Spain and Mexico, this research seeks to provide more information on the composition and performance of these networks and on the factors that can help less developed regions —performer and artifacts-wise— achieve similar network refinement levels. More specifically,

this study seeks to help develop new ways to acquire transfer, and express knowledge in the realms of modern biotechnology. To put it differently, it seeks to add more elements that can help the actors within this technology progress “downstream” together as a unified group with similar interests and goals.

INTRODUCTION

This research puts forward an alternative methodology for the study of knowledge accumulation and innovation production in modern biotech. More specifically, it presents the results of a series of thought experiments designed to measure and contrast the effects of structural differences in the performance of Mexico and Spain's modern biotech innovation systems.¹

Borrowing concepts from neoclassical, endogenous growth, and regional systems of innovation theories—and supplementing these with empirical data analysis findings—it introduces a systems dynamics model that helps better understand how technological change processes in this sector are being shaped by the interaction of multiple factors and agents, including the government. Using variations of this model, it further shows the results of evaluating which alternative institutional set-ups support a stronger dynamic performance of the sector as measured by a series of response variables. The results of this process conclude that, although the response for most variables is greater when the model is testing Spain's modern biotech system than when testing that of Mexico, the level of the key variable measuring the creation of marketable biotech products is more efficient in the short run and only marginally less in the mid and long runs in the latter model's test than in the former. Further, this methodology suggests that if Mexico's current structural arrangement—as represented by the model—is modified into that identified in this research as most response-inducing, the capacity of that country's system to promote the creation of these types of products would increase above that currently estimated for it and pos-

¹ Lundvall et al. (2009) suggests that the (national/regional/sectoral) innovation system is a focusing device aiming at analyzing and understanding processes of innovation (rather than allocation) where agents interact and learn (rather than engage in rational choice). He further proposes that the aim of using this device is to find out which alternative institutional set-ups support strong dynamic performance of a (national/regional) economy or a sector.

sibly above that resulting from exclusively adopting elements of Spain's system of innovation for modern biotech. A series of policy recommendations for Mexico come forth from these findings as possible paths that can lead to achieve a higher innovation potential in modern biotech in that country.

Additionally, this study provides more elements to the ongoing conversation on how to bridge the 'Systems of Innovation' approach for explaining regional knowledge-based economic performance with the methodology and mathematical modeling technique for framing, understanding, and discussing complex issues put forward by 'Systems Dynamics.' Moreover, this approach opens the door for future alternative thought experiments designed to achieve a deeper understanding of how organizations, institutions, market structure, market imperfections, trade, government policy, and the legal framework in many domains affect long-run growth, through their effects on economic agents' incentives to engage in knowledge producing activities associated to modern biotech.

From an academic perspective, this work can be considered a further attempt to gather more information about what happens inside the "black boxes" to which scientific production and innovation processes are generally associated with. In doing so, it also seeks to offer more resources towards helping understand the limits of knowledge accumulation and the role knowledge itself plays within innovation processes. Lastly, it provides more elements to imply that the effectiveness of modern biotech innovation systems (or those of any technology), as measured by the performance of its individual parts, may be in function of their complexity and —to a lesser extent— of the policies followed by the actors operating within in these.

Structure of the Paper

This document is divided into four chapters: 1) The first chapter defines modern biotech as a set of technological systems and explains some of the central limitations of various mainstream theoretical approaches to the study of innovation and their impact on this technology. It also introduces the principles behind the systems of innovation approach followed by this research; 2) the second chapter provides a detailed account of the interview processes and the analysis of results per country (Mexico, Spain), framework (institutional, regulatory), and key system components (actors, networks, and institutions; funding sources; research and human capital; regulation, policies, and planning; and international links). It closes with a section on general and particular findings that facilitate contrasting observations; 3) The third chapter explains and justifies the approach followed for the design of the systems dynamics model used to test both nations' modern biotech systems of innovation. It presents a detailed description of the model and its parts and how these associate —when they do— with the economics theoretical principles or views and opinions of the various actors interviewed that helped define them. In addition, this section both breaks down the methodology followed to obtain and assess the response of specific variables and presents the outcome from contrasting the response levels of selected variables using different versions of the model; and, 4) the fourth and closing chapter offers final thoughts and a series of policy recommendations for Mexico based on the obtained results. It finishes with a number of theoretical recommendations for academics and professionals engaged in the study of scientific development. Other supporting documents and additional results tables are found within the document's multiple appendixes.

In more detail, the opening chapter defines modern biotechnology as a set of

technological systems and introduces a pair of challenges identified throughout the new growth economics and technological change literatures as the possible key factors behind the emergence of institutions and institutional changes associated to this technology. These challenges are also framed here as inducing limitations to mainstream economic analysis and thus, viewed as the perfect excuse for the design of alternative methodologies that can offer a deeper understanding of their effects on innovation processes. More specifically, 1) the complexity of defining adequate incentives for basic scientific endeavor, and 2) the difficulty of establishing channels that allow a sustained and efficient transformation of the results of basic scientific endeavor into technological advancements and further into innovations, are depicted here as promoting these institutional changes. Additionally, the chapter explains that such limitations approach stems from the fact that knowledge, information, and ideas—found at the core of all scientific endeavors— can be considered as quasi-public goods due to their non-rival character. This analysis also delves into the specific effects that these identified challenges—plus knowledge’s non-rivalry— have on modern biotech, providing a direct analogy between information in electronic format and genetic material as an example. Finally, it puts forward the premise that the pace at which innovation systems adjust to this technology’s rapid advancements has also played a considerable role in defining their structural composition and performance. The section ends with a brief review of the economics of the systems approach.

The second chapter presents a detailed description of the elements composing Mexico and Spain’s innovation systems for modern biotech based on information gathered on-site and the results obtained from a series of interviews conducted in both countries. This section also describes their structure, behav-

ior, and performance and defines them as Modern Bio-technological Systems, MBTS within more general National Systems of Innovation, NSI. Each NSI is carefully analyzed to pin down which specific structural arrangements (institutions, policies, and regulations) compose these MBTS, and which of these elements developed to cope with the above mentioned challenges when these directly affect biotech locally. The findings of this comparison exercise helps shed more light on the elements that may be giving Spain's system an edge over Mexico's. It closes with both a general observations section, considering the most evident differences between these systems (regional economic and geopolitical organization; resource flow; programmatic mechanisms; local views regarding new technologies; etc.), and a particular observations one, listing the institutional and regulatory elements of each. The multiple components and parameters pinpointed in this chapter also assisted in sketching the general systems dynamics model and its adapted versions for each country presented in the following section.

The third chapter offers a detailed and thorough explanation of the general model's design and sub-systems (research, development, innovation management, resource management, R&D policy), making emphasis on the adapted biological evolutionary process found at its core. It starts with a brief explanation of how this model helps understanding the structure of both systems and how the overall exercise provides more data to estimate if Spain's MBTS truly outperforms that of Mexico. This chapter's section also emphasizes the fact that the model's objective is not to determine and maximize a production function for research and development activities, R&D with specific output elasticities between its inputs. Instead, it puts forward the notion that this approach presents a model that —by taking into account the interactions between the stochastic

nature of discovery, the continuous advancements in R&D methods, and the resources available— centers on assessing how the sector’s potential varies over time. It also explains how this “general” model is altered through a series of components (“switches” and “sliders”) and initial conditions that allow it to represent more closely abstract versions of either countries’ system.

This chapter also presents the experiment design, explaining that —instead of alternative models— variations to the general model’s structure are considered “treatments” in this analytical process. Therefore, subjecting the general model to multiple treatments, the response of key variables can be obtained and compared in a systemized manner for each of these. Treatments are then presented by rank (best, moderate, or unsatisfactory) based on the effect these induced on the assessed variables. This segment also offers a first hint of the overall research findings, showing that the treatment representing Spain ranked among the best and that of Mexico among the unsatisfactory. Thus, confirming that alterations to the general model’s structure indeed have an effect on variable response, eliminating the possibility that such variations could be induced exclusively by changes on the value of the general model’s initial conditions.

The two next sections in this chapter analyze the results of the model when adapted to represent Spain and Mexico (in other words, when the general model is subjected to the treatment and its initial conditions changed to represent those of each countries’ system), also explaining the methodology followed to assess the response of the 15 selected variables in the short, mid, and long terms. Each section presents the degree of response and change that each variable displayed, allowing to conclude that Spain’s system —as defined by the model— in fact induces a higher response in most variables than that produced by the adapted version representing Mexico. However, the comparison concludes that

the model for Mexico outperforms that of Spain in the production of new marketable products in the short term and only remains marginally below it in the mid and long terms. Additionally, it suggests that if Mexico's current structural arrangement—as represented by the model—is modified into that identified in this study as most response-inducing, the capacity to promote the creation of new markets for products derived from biotech of that country's system would increase above its currently estimated levels and possibly above those of Spain.

The fourth and last chapter presents a list of policy recommendations. Essentially, it suggests that Mexico, instead of simply copying those elements that appear to be making Spain's system more efficient, it should develop "tropicalized" versions of these. This segment also suggests that Mexico should take more advantage of its geographical location and seek the establishment of regional agreements regarding investment, access to genetic resources, intellectual property rights, IPRs , and venture capital investment within the NAFTA framework. It concludes with a series of theoretical considerations that can serve as the basis for future research endeavors.

CHAPTER 1

MODERN BIOTECH SYSTEMS OF INNOVATION

1.1 Defining Modern Biotech as a Set of Technological Systems

Modern biotech has no defined boundaries. As a scientific process, it **has produced a continuous and fast-paced redefinition of both the scope and borders of basic and applied research.** As a technology, its novelty and wide-range applicability has altered the conventional limits of law, economics, and other social structures **inducing adjustments to some of the most fundamental principles within generally accepted theories of property, economic growth, and technological change globally.** Simultaneously, these changes—developing within a complex network of agents and organizations—have encouraged the regional rise and formation of various new institutions, which in some cases both assist further promoting the advancement of research in modern biotech and allow the development of derivative technologies, products, and services, thus, improving the prospect of benefiting from the economic and social welfare that stems from innovation in this area. Based on these traits **modern biotech can be understood as a dynamic network of technological systems of innovation in which R&D processes for the discovery, application, transfer, and transformation of new knowledge take place.** These processes induce both the formation of new institutions and organizations and the transformation of existing ones. However, evidence shows that such technology-induced adjustments do not occur simultaneously nor at the same rate or pace across all countries and regions currently engaged in modern biotech activities despite globalization and the noticeable advancements in Information Technologies, IT . This has also made evident both a regional disparity in the adapting capacity of existing

institutions and of the rate at which this happens as well as a regional variance in the ability to induce the formation of original pro-modern biotech institutions and organizations, ergo, reducing the likelihood of achieving higher economic development and social welfare levels for those regions adjusting at a slower pace.

1.2 General Challenges and the Systems of Innovation

Many numerous new institutions and changes to existing ones are believed to be emerging out of the necessity to cope with a series of challenges identified throughout the new growth economics and technological change literature as directly affecting the development and management of innovation; theory suggests that these help explain and justify many of the current existing incentives, behavior and performance of agents working within these systems of innovation and, more specifically, of those within their networks devoted to modern biotechnology, referred to as Modern Bio-technological Systems, MBTS. A vast majority of these challenges are recognized as deriving from: **1) the complexity of defining adequate incentives for basic scientific endeavor (knowledge and information production); 2) the difficulty of establishing channels that allow a sustained and efficient transformation of the results of basic scientific endeavor into technological advancements and further into innovation (knowledge and information distribution and application)**. On the one hand, such a twofold approach stems from the premise that knowledge, information and ideas —at the core of all scientific activity and especially of modern biotech— can be considered as quasi-public goods due to their nonrival character (Arrow, 1959; Romer, 1990; Jones and Romer, 2009). Based on this characteristic and due to the fact that their value increases in proportion to the number of

users, knowledge, information and ideas (information, from hereon)¹ also alter feasible and optimal economic institutions (as proposed by neoclassical economics) by introducing scale effects. These nonrivalry-induced effects make both its full appropriation and its optimal allocation, as described within neoclassical growth models, virtually unattainable. Therefore, profit-maximizing private entities (who abide to these principles) are induced into shunning most research-intensive ventures if not allured with compelling incentives not to do so.² Further, this particular attribute also points towards the fact that any kind of interaction that lets someone associate with numerous others like her and share the information each has discovered is beneficial from an economics and social welfare perspective; if many are the individuals or entities that can benefit from such information, then there are efficiency gains to be had from transferring it and from connecting all possible beneficiaries together so it can be used everywhere as soon as it is discovered somewhere. No matter how it is communicated and reused, nonrivalry by itself creates strong incentives for economic integration among the largest possible group of people and the profit derived from it may not become exhausted at any finite population size (Jones and Romer, 2009). The consequences of these effects —as a result— provide further evidence of the fact that the institutions of complete property rights and perfect competition that work adequately in a world consisted solely of rival goods

¹The Oxford English Dictionary (OED, 2011) defines idea as: “Any product of mental apprehension or activity, existing in the mind as an object of knowledge or thought; an item of knowledge or belief; a thought, conception, notion; a way of thinking.” The same source defines information as: “The action or fact of imparting the knowledge of a fact or occurrence.” Although there are fundamental differences between these two concepts, the former can be identified as contained within the latter, more so when the product of such mental activity results in the discovery of a natural occurring phenomena or law which, eventually, will become common knowledge.

² Jones and Romer (2009) point out the fact that in neoclassical models efficiency in use dictates price equal to marginal cost. But with the presence of increasing returns, there is insufficient output to pay each input its marginal product; generally, these models suggest that price must exceed marginal cost somewhere to provide the incentive for profit maximizing private firms to create new ideas.

no longer deliver the optimal allocation of resources in one containing mostly information (*Ibid*). Moreover, these also support the notion of an existing association between the free flows of information and people —as in the effects of globalization, urbanization, and those derived from the IT revolution— and the extent and formation of markets for new knowledge and innovation.

On the other hand, this approach also emerges from the fact that systematically transforming the product of basic research (information) in its purest forms into the fundamental building blocks of future technologies and innovations (invention) with potential positive economic growth is quite complex a task. Both information (in its purest forms) and the randomness of invention are at the core of this transformative tension in modern biotech. The central economic fact governing the process of research and invention (scientific activity) is that these activities are devoted to the production information (and of finding ways to apply it); by its very definition, [scientific activity] must be a risky process in that the output (information obtained) cannot be predicted perfectly from the inputs (Arrow, 1959). As previously mentioned, private profit-maximizing entities discriminate against investing in such research-intensive and invention processes in great part due to the absence of devices that can efficiently shift such risks away from them. Further, the design of such risk-shifting instruments for the particular case of scientific activity from the standpoint of a central planner becomes quite intricate due to the underlying presence of a “moral factor” which —if not pondered adequately— may very well hamper their anticipated enticement purpose.³ This, within a free-market economy, in-

³ Arrow (1959) defines moral factor as the difficulty to distinguish between the state of nature and a decision by the risk-bearer (insured). He suggests that —in general— any device for shifting risks can have the effect of diluting incentives; substitutive motivations, whether pecuniary or not, may be found, but the dilemma of the moral factor can never be completely removed. In the particular case of invention (product or process), an insurance against failure could weaken the incentives to succeed.

duces the imperfect solution where only large-scale corporations —capable of conducting multiple small-scale research projects (each costing close to nothing when compared to their net corporation revenue)— can simultaneously engage in basic research and serve as their own “insurers” by internally diffusing investment risks. Within such a framework there are no incentives for the development of new start-up private enterprises while existing ones tend to steer away from such research activities remaining at the margin of production and access to information and, thus, of generating innovation. Although history suggests that chance —more than a systemic and staged linking process elicited on request— brings technological change (Kamien and Schwartz, 1982), the review of these two central challenges provide additional evidence to suggest that market equilibrium —within the frame of neoclassical theory— would not optimally allocate resources for scientific activity, therefore justifying some form of policy intervention to reduce these.⁴ In practice, some of the above-mentioned paradigm-changing advancements induced by modern biotech have indeed encouraged the transformation and rise of multiple institutions aiming at bridging such information-to-innovation and sector linkage gaps. Furthermore, these have made more evident the unequivocal association between: a) the evolution and establishment of new institutions (aiming at reducing the effects resulting from these challenges); b) the ways in which information and its sources are produced (this includes human capital formation); and c) the scale of population within regions (as the source of both human capital and information). A closer look at the dynamics and networks existing within these systems of innovation, particularly those of Mexico and Spain, provides more information

⁴Adding even more complexity to the design and planning for institutional change is the fact that basic research is also carried out for a series of reasons beyond a fundamental quest for knowledge or applicability, including self-expression, altruism, and prestige (Kamien and Schwartz, 1982)

on how these challenges are reshaping the institutional, economic, and social landscapes and what resulting outcomes appear as better suited to face these.

1.3 General Challenges and their Effect on Modern Biotech

While these challenges equally affect all areas of scientific endeavor, modern biotech appears to be more susceptible to these for multiple reasons; as a scientific activity mostly focused on defining and conducting processes of artificial genetic material manipulation, it operates with and mostly produces information from the ubiquitous DNA molecule and its parts. Found within any living organism, access to DNA is virtually as boundless as it is widespread, turning most efforts in the direction of claiming exclusive rights over its physical parts (the nucleic acids composing the molecule itself, its genes and their sequence, or any other of its components) or the information expressed and contained in it or in any of its parts quite impractical.⁵ Conversely, this also makes protecting and enforcing property rights exerted over any information contained within it or its parts equally as intricate (I will address this matter shortly). Although some of these artificially-induced biological alterations and processes may indeed create completely new organisms or induce processes not conventionally occurring in nature, it is both, the methods followed to produce such changes and the information obtained through them, that could indeed become of partial proprietary excludability under most existing IPRs statutes. In most cases,

⁵Although there are three broad categories of biological molecules —carbohydrates, lipids, and proteins— the principal determinants of the basic structure and function of any living organism are the proteins coded for in its DNA (Bohrer, 2007). DNA stands for deoxyribonucleic acid, the three-dimensional structure containing the basic genetic material that determines the heredity of all plants and animals and some viruses. A gene can be considered as a stretch of DNA, which contains the complete set of instructions for the construction of a particular protein (chain of amino acids with a particular function). In a complex, or multi-cellular organism —whether an octopus or a human— virtually every cell of any single creature contains exactly the same genetic information, or DNA, as every other cell of that creature (*Ibid*).

however, this is the only subject matter over which IPRs can be filled for, often more than over the resulting genetically modified organisms, GMOs or living genetically modified organisms, LGMOs, their altered genetic structure, genes, or parts of these.⁶ Furthermore, this information, more often than not, becomes the single proprietary part of the process displaying the highest economic and business value.

In addition to information the most frequent outcomes deriving from modern biotech activities are the previously mentioned GMOs, LGMOs or parts of these. These novel organisms —now containing the new information in the form of genetic modifications within their recombined genetic structures— carry within themselves the results of long and rigorous scientific endeavor. Like any other living organism, these may still display replicating or reproducing capacities; having the potential to pass-on such information to their offspring without depleting it and with barely no effort.⁷ This capacity is com-

⁶From a legal viewpoint this varies regionally. In the U.S. after *Diamond v. Chakrabarty* (447 U.S. 303 (1980)) patents can be issued over living organisms under 35 U.S.C. 101. Yet this was hardly the end of inquiries into what can be claimed as patentable subject matter in a modern biotech patent application. The USPTO later ruled over claims over genetically modified multi-cellular or higher organisms as patentable subject matter, *In Re Allen* (2 U.S.P.Q2d 1425, Bd. Pat. App. 1985), which held human multi-cellular organisms could as patentable (*op.cit*). The ultimate test for the patentability of higher organisms was presented in the claimed invention of a transgenic mouse, which expressed a cancer-related variant of a gene involved in cell growth or replication, by Harvard University. The USPTO issued the patent (U.S. Pat.4,873,191) allowing living organisms, including mammals, which have been genetically modified to be considered composition of matter and therefore patentable subject matter under 101 in the United States (*Ibid*). The EU position is that it will allow patents on methods of genetically modifying animals as long as the method is not limited to one species. The EU also allows claims to methods of using genetically modified animals, subject that these methods are applicable to more than one species. It will not allow patents on a species and some permits can be denied if the genetic modification is considered to produce suffering to the new organism without any substantial benefit for men or animal. Additionally, each member state can bar these practices based on the host country's law concerning the humane treatment of animals and other ethical concerns (*Ibid*). In Canada, the Canadian Supreme Court decided that animals were not patentable subject matter within the scope of the local regulation. However, in the particular case of the oncomouse, claims were allowed to various components and methods used in its creation, allowing the patent holder some protection against local competition (*Ibid*).

⁷A low stability of the genetic modification within the DNA structure of such organisms or the help of naturally occurring genetic modification processes (such as viral infection) could also

monly referred to in the economics literature as near-zero transaction costs and is a highly common trait of information in the contemporary IT Era. Moreover, such replication ability reduces even more the likelihood of full appropriability and containment; more so if these types of organisms (or their parts) become boundless within less restricted access environments or even reach their way into natural ecosystems. Then again, these effects are somehow analogous to information's low transaction and transmission costs within open or less restricted access networks. Such transmission/inheritance abilities —along with the ubiquitous presence of DNA within all living organisms and viruses— provide more elements supporting the argument that not only the information resulting from modern biotech activities behaves —like any other type of information— as a quasi-public good, but also that the physical outcomes of genetic manipulation and research i.e. GMOs, LGMOs, or its parts, also somehow display public good traits.

1.4 New Policies and the Systems of Innovation Approach

Like other areas of science, appropriating information as a basis for future research is much more complex than appropriating its use in producing products due to the impossibility of knowing its full applicability *a priori* (Arrow, 1959).⁸ In addition, theory suggests that such information appropriation reduces the possibility of creating social and economic benefits deriving from its sharing, thus, curtailing the formation of channels that promote a sustained and efficient

aid transferring such information throughout vectors and beyond artificially created barriers originally estimated for its containment (*op.cit*).

⁸Arrow also suggests that “the value of information for use in developing more information is much more conjectural than its use in production and thus more likely to be underestimated, so that if a price is charged for it, the demand is even more likely to be sub-optimal” (Arrow, 1959).

transformation of the results of basic research in modern biotech into technological advancements and innovation in multiple sectors. This observable fact affects modern biotech more intensely because discovery in modern biotech becomes more difficult as barriers to information become more and more sophisticated and better enforced. Although pervasive in nature, limiting access to the available information existing within the genetic structure of living organisms (genotypes) will further blur the distinction between property, contracts, and physical products (Burk, 2004).⁹ Moreover, if such enclosure happens within economies closer to the modern biotech technological development frontier, it becomes easy to estimate that accessing —and producing— such information will become even harder for emerging economies as time goes by.

Many policies within both the public and private realms have indeed been designed to reduce the effects of these challenges (i.e. intellectual property rights protection, direct subsidies, horizontal/vertical organization, etc.). Yet, most appear as attempting to induce the R&D sector into behaving in a manner that is analogous to the neoclassical economics theory standard definition of a productive sector. However, these policies seem to overlook the fact that connections, linkages, channels, and feedbacks are the main components of these systems (both for general R&D and modern biotech). They have also contributed in the transformation and development of institutions, the creation of information (as a quasi-public good), and of better ways to manage it. A more systems oriented approach offers new perspectives on the behavior of the sector and may well shed more light on how these challenges are being addressed and how these can be tackled in the future.

⁹The behavior of this sector from a market perspective is quite analogous to that of the microprocessors put forward by Segerstrom (2007) in his paper “Intel Economics.”

1.5 The Economics of the Systems Approach

In economics literature it is generally accepted that scientific endeavor and technological change are important sources of productivity growth and positive social welfare. Conventionally, the analysis of these as sources of innovation has been approached from a perspective based on the presumption that innovative processes can be decomposed into several isolated phases that take place in a strictly proceeding sequence. Balzat (2006) suggests that in the analysis of technical change within the economics of innovation literature many of the earlier and more abstract models of technical change and innovation have been crowded out. In his view “these traditional and usually formal models, being rooted in mainstream economic theory, a central role has been typically given to the calculation of optimal decision-making in the context of innovative behavior, comparable to the derivation of optimal investment decisions. Technical change has therefore been treated as an exogenous event, while the specific features and determinants of real and modern innovation processes have been largely abstracted from. Precisely in this latter respect, namely in the explicit consideration of the attributives of real innovative activity on the national level, the national innovation systems concept possesses a mayor strength.”

Departing from such linear schemes, the more systems-theoretic approach known as Systems of Innovation (SI) proposes that the analysis of the behavior and effects of innovation are better understood when viewed as part of an evolving system characterized by interdependencies between market and non-market activities, a variety of actors and multiple surrounding conditions (Balzat, 2006). Derivative and more spatial-specific forms of this approach are the notions of national (NSI) and regional (RSI) systems of innovation. For Aghion et al. (2009) the terminology also varies “to increase the aware-

ness of the close linkage between technological change and innovation with advances in science, on the one hand, and the set of socio-economic institutions operating in a given context, on the other encoura[ging] the conceptualization of science, technology, innovation, and growth systems, STIGS as appropriate subject of policy-oriented research.”

Displaying even more specificity is the terminology of technological systems, TS which Carlsson and Jacobsson (1997) define as “a network or network of agents interacting in a specific technology area under a particular institutional infrastructure to generate, diffuse, and utilize [a specific] technology.” For them TS are defined in terms of knowledge and competence flows rather than flows of ordinary goods and services, consisting of dynamic knowledge and competence networks. This systems notion of innovation not only has gained relevance within the new growth economics and endogenous technological change and innovation literatures and its scientific communities but also acceptance among decision-makers when these work on defining state-of-the-art policies to encourage the local performance of research and development (R&D). Furthermore, this approach offers alternative perspectives to the study and understanding of the effects of the series of challenges commonly identified within mainstream economics theory as affecting the fundamentals of R&D activities mentioned earlier and, consequently, of modern biotech. These challenges, as suggested earlier, are often singled out to be key motors behind the fast and continuous redefinition of the institutional composition of MBTS and—consequently— of systems of innovation globally.

CHAPTER 2

NETWORKS AND INSTITUTIONS OF TWO SYSTEMS OF INNOVATION

2.1 Two Countries, Two Systems, One Technology

This section presents a description of both Mexico and Spain's MBTS operating within each country's NSI to put forward more elements to support the initial arguments suggesting that: a) modern biotech is redefining the boundaries of R&D inducing the transformation and creation of new institutions at a much faster pace than ever before; b) a number of these transformed and newly created institutions not only surged to attend a series of challenges that mainstream economics theory has detected as affecting the performance, management and planning of R&D but also emanated from the interaction of multiple market and non-market activities, a variety of actors and multiple surrounding conditions within a systems environment; c) that a more systems-theoretic approach may not only help better understand how these new institutions rise and evolve, but also could provide different perspectives on how to address the identified challenges and design more *ad hoc* policies to reduce these; and d) that the difference in maturity and performance between Mexico and Spain's MBTS is partially due to the fact that, when addressing the above mentioned challenges, actors within Spain's MBTS and NSI follow a more systems-theoretic approach to develop policies and plans (as opposed to a more conventional approach mostly based on mainstream economic growth theory followed in Mexico to do so).

The chapter is divided as follows; the first section consists of detailed information about the structure, behavior, and performance of Mexico and Spain's NSI supporting such description with data and the views of various key actors within these systems collected during fieldwork in both countries. Here each

NSI is dissected as carefully as possible in order to pin down the elements within these also composing their local MBTS. This description identifies what specific institutional arrangements (institutions, policies, and regulations) within both MBTS and NSI have developed to cope with the previously mentioned challenges when these seem to be directly affecting the advancement of modern biotech as a sector locally. This exercise also aims at detecting what factors and environments at the national and regional levels facilitated their rise and establishment. In the second section these results are contrasted in a further attempt to recognize elements that may offer more light on why Spain's MBTS appear as evolving faster and displaying more efficiency traits in promoting modern biotech than Mexico's. A final part presents a comparative list of components and parameters that helped sketching a systems dynamics representation of each country's MBTS (specifying their main components, behavior, and interactions within these) presented in the following chapter. This modeling experiment will allow contrasting at a more tangible level what instruments and/or institutions, links between these, and other factors seem to have allowed Spain's MBTS a more effective development than that of its Mexican counterpart as well as shed additional information on how realistic can the possibility of fostering the formation of analogous versions of such institutions in the latter country be.

2.2 Two Systems of Innovation: The Cases of Mexico and Spain.

National and regional systems of innovation are generally compiled by both elements and initiatives stemming from both the private and the public sectors. Identifying these central elements —and those within these composing

both systems' MBTS— is the most logical starting point for this analysis. To do so, I mainly rely on collected data describing how these two NSI operate as well as the results of the analysis of a series of interviews with key actors currently working within both systems at the MBTS level, which I gathered over the time span of three years (2008-2010). This section opens with a brief account of how I collected and organized the information, and then turns to the thorough description of the institutional and regulatory frameworks for each NSI and MBTS.

Actors

The selection of participants whose views supplement this analysis was a complex one. While trying to balance the representativeness of each tentative participant, I also tried estimating their relative influence and weight within each of their areas of expertise, making sure their views and opinions would add value to this study. Additionally, I classified my selection of actors within four general sectors (government, private sector, research, and NGOs) where these most commonly operate and which are clearly identifiable in both countries (see table 2.1). Although I have previously met some of these actors in person —particularly those from Mexico— I had to work my way into scheduling interviews with many whom I have never met nor have had any form of contact with before. In various occasions their names were referred to me by other actors during interview sessions; most I identified while engaged in literature review, and others were accompanying interviewed actors during our session and later decided to participate in the research as well. In the end, I identified a total of 25 individuals from both countries —15 Mexican and 10 Spanish— that filled the key actor requirements (representativeness, top institutional rank, ver-

Table 2.1: Number of Actors by Country and Sector

Country	Sector				Total
	Government ^a	Private ^b	Research ^c	NGO ^d	
Spain	2	2	3	2	9
Mexico	3	3	4	2	12
Total ^e	5	5	7	4	21

^a Includes federal, state, and regional.

^b Includes financial sector.

^c Includes both public and private.

^d Includes environmental and other.

^e Some actors are allocated into more than one category.

ifiable contribution to her area of expertise, etc.), from which only 16 (6 and 10, respectively) finally agreed to participate in the sixty-minute interview session.

While the sample can be considered relatively small and the outcome gave a low 64% response, the fact that five out of the 16 participants requested being considered in more than one category (government-research, private sector-research, research-NGO, or NGO-research) and agreed to answer the same questions from either perspective boosted the total to 21 independent interviews, a figure closer to my initial target of 25. In addition, each participant's corroborated top rank position and solid reputation within their organization or institution, as well as tangible contribution to their field and area of expertise through papers, opinion, or political or entrepreneurial activities in their respective countries added validity to the final concise but acceptable outcome. To maintain the actors' anonymity each was assigned a particular code composed by either the capital letter "S" or "M," depending on their country, and a randomly generated number between 1 and 9 (for Spain) or between 1 and 12 (for Mexico). Furthermore, to provide more context between the views expressed and these actors, these resulting codes are also arranged within the four sectors Government, Private, Research, and NGO (see table 2.2). Each of the codes is

Table 2.2: Actors by Country, Sector and Code

Country	Sector			
	Government	Private	Research	NGO
Spain	S5, S7	S1, S9	S3, S4, S8	S2, S6
Mexico	M2, M5, M11	M1, M7, M9	M3, M4, M10, M12	M6, M8

also composed by the initial letter of the sector in which the actor offered to provide viewpoints (G, P, R, or N). Lastly, two different codes were assigned to those actors who agreed to provide views from the perspective of more than one category.

Frameworks

As mentioned earlier, the initial section sought to describe the key elements within the institutional and regulatory frameworks of each MBTS within both nations' SI. To do so, I developed a table containing the features estimated as most generally composing both frameworks, which could easily be identified in both nations. The table is mainly divided into two framework categories: a) institutional, and b) regulatory, each having particular key elements, such as actors, actor-networks, funding structures, as well as research and human capital formation for the former, and regulation, policies and planning, and international links for the latter. This also allowed complementing the information more systematically with the views of the interviewed actors while also providing identifiable and easier to contrast traits for each system (see table 2.3).

2.2.1 Institutional Frameworks

Reviewing in more detail the institutional components of both NSI and MBTS in each country provides information on their nature and that of their networks,

Table 2.3: Frameworks and Key System Components

Institutional	Regulatory
Actors, Networks, and Infrastructure Funding Sources Research and Human Capital	Regulation, Policies and Planning International Links

how these came to be the way they currently are, how their elements operate within them when defining and applying policies, and how they seem to be evolving.

In this initial delineation of the institutional components of both sets of systems I start by describing the actors and networks compiling these and working to define each. I focus more on the institutional actors—as opposed to individuals or persons—and their role within an ever-changing system of systems as these come into play and evolve in a quest to retain their validity. I then describe the framework’s central elements committed to creating information and its sources through research and human capital formation activities, as well as aiming to form a solid infrastructure for these investigative and formative activities to take place. Lastly, I point out what international links and decision-making processes have also helped shape these structures in both nations.

2.2.2 Mexico

Actors, Networks, and Infrastructure

In Mexico there are two central institutional actors heading the intricate regulation and promotion instruments within the local NIS and MBTS: the National Council for Science and Technology, CONACyT and the Inter-secretarial Commission on Biosafety of Genetically Modified Organisms, CIBIOGEM . In particular, CONACyT promotes the advancement of biotech as part of the general

sciences, developing exclusive policies and programs aiming at this goal and at creating human capital and inducing linkage with other productive sectors. On the other hand, CIBIOGEM coordinates those policies oriented to the safe development and use of GMOs and orchestrates their application by its multiple executive federal secretariats members. The commission —composed by the heads of the Health, Agriculture, Livestock, Rural Development, Fisheries and Food, SAGARPA; Environment and Natural Resources, SEMARNAT; Finance and Public Credit, SHCP; Economy, SE; and Public Education, SEP, secretariats as well as the General Director of the CONACyT— also engages in promotional activities mostly through various specialized committees; these multidisciplinary forums aim at facilitating the interaction between actors and experts representing different areas of knowledge easing their engagement in activities that range from defining terms of reference and rules for research collaboration to issuing recommendations for particular cases. It also harmonizes federal policies with state and local policies and collaborates with their authorities in their implementation. Furthermore, it manages information on all GMOs and LGMOs as well as authorizations and permits issued for these and their use. It also participates in technical assessment and decision-making processes regarding these organisms —including the establishment of GMO-free zones and experimental areas— through various sub-committees. For many actors the commission is the most salient element composing the current system as enclosed within the opinion of actor M3-R:

Even before having juridical character, CIBIOGEM helped promote the enacting of the current biosafety and modern biotech regulation. Serving also as model for other developing nations pursuing the advancement of these technologies it eagerly participated on the drafting of the law's by-laws (*Reglamento*), its internal operation rules, and will certainly continue to play a key role in the drafting of all future norms and standards operating over this highly complex area.

Depending on their use, the secretariats of agriculture, environment, and health play more executive roles when dealing with the biosafety of GMOs and the safety of products made with or containing these. On genomics, the roles vary depending on the type of information dealt with; the health secretariat has a lead role when studies on the human genome are conducted, commonly assisted by a series of bioethics committees. Research and the management of animal or plant genomics fall in the hands of agriculture and environment secretariats, assisted by CIBIOGEM and its various subcommittees. More specialized institutions within this structure are localized in several of the previously mentioned three central sectors. Within agriculture, the core institutional actors composing the system are the National Service of Agro-alimentary Health, Safety, and Quality, SENASICA; the Mexican Fishery Institute, IMP; nomenclatureIMP Mexican Fishery Institute the National Fishery, Agriculture, and Livestock Research Institute, INIFAP; as well as the Post-Graduates College and the Autonomous University of *Chapingo*. Although having a quite robust role within the local modern biotech institutional framework —ranging from basic research activities and high-end human capital formation to the safety assessment of derived products— actor M11-G considers that the sector still requires more coordination between the existing institutions and better fine-tuning of its general strategies.

Addressing modern biotech from the perspective of environmental protection are the National Ecology Institute, INE; the Federal Environmental Protection Agency, PROFEPA; and the National Commission for the Knowledge and Use of Biodiversity, CONABIO. Although being highly specialized and highly technical, actors M5-G and M12-R consider it as one of the weakest links of this institutional framework. In their view, this is due to the common misinterpreta-

tion that risk and uncertainty reducing and management procedures followed for some of the outputs of modern biotech —especially those that could have consequences affecting public goods of the caliber of the numerous local ecosystems and native varieties of plant and animals— appear as curtailing the flow of science and business activities. For actor M5-G:

One of the system's biggest flaws has to do with the disconnection between modern biotechnology and biosafety; I am convinced that—in Mexico— there is no political will to advance biosafety. This creates a disconnection between these two intimate associated areas. For me, biosafety means engaging in modern biotechnology activities in a safe and responsible way—it is the reduction of risk to inconsequential levels—. For other actors, this means curtailing the advancement of science and, thus, the possibility of engaging in business development. Difficulties will continue surfacing as long as this perception prevails, creating a slippery slope for the overall advancement of this technology locally.

The most robust segment of this institutional configuration appears being that pertaining to health and human services. Within this sector, the Federal Commission for the Protection against Sanitary Risk, COFEPRIS, and other departments within the health secretariat dealing with consumer products production standards, advertisement, and distribution, as well as those focusing on research relative to human health play pivotal roles in ensuring the safety, use and manufacturing of modern biotech derived products, especially pharmaceuticals. Some of the most recent additions to this intricate institutional network aiming at linking science and other productive sectors associated to modern biotech also fall within the human health part of the system's institutional frame; On the one hand, and mainly targeting human health services and products these newly formed institutions are in charge of the promoting and regulating human genomics in Mexico. On the other hand, these coordinate and engage in basic research in these areas through the Genomic Medicine Institute, INMEGEN—one of the most recent members of the Highly Specialized

Hospitals System known as the National Health Institutes, INS—. In charge of coordinating the entire INS' network efforts and policies, while —at the same time— having the general role of producing and implementing public policy strategies in health, including areas related to modern biotech and genomics, is a commission composed by expert members from within the health network. The network's central objectives are advancing project linkage at the various levels of federalism (national, regional, state, etc.) and developing more efficient managerial and project funding schemes. Of recent formation and key institutional player is the National Bioethics Commission, CNBio whose general objectives aim at advancing a more bioethics-aware culture in Mexico. Its more specific role aims at defining national policies, establishing those related to bioethics in public health, and acting as the national advisory body to the government on this area. As part of these efforts, the commission promotes the establishment of bioethics commissions in every state, issues recommendations in topics like cloning and property over genetic material, and promotes public participation through various forums. In 2004 the commission incorporated the functions of the National Human Genome Commission whose objectives overlapped with those of the CNBio.

Having the capacity to ratify international treaties and delineate the regulatory framework affecting modern biotech and any of its derivative products and services and lines of research, the senate and the chamber of deputies are two of the most active players in this system. Through its multiple congressional commissions operating in both chambers, the legislative branch is in charge of reviewing and putting forward regulatory and promotional instruments that can affect the development of modern biotech in much higher degree and in a much faster way than any other institutional actor within this framework. Mainly, the

members of the science and technology, environment, agriculture, health, rural development, and trade and industry commissions of both chambers have in their hands the capacity to alter the path and pace at which this new technology develops locally. These processes, however, are often prone to distortion; permeated by a variety of political and economic views and interests, discussions within these committees often end up too politicized. Actor M9-P pointed out this fact by saying:

It gives me the impression that some groups, from within a specific political stance, believe that the pace at which modern biotech is moving is way too fast. Maybe because they sense that some of the new paths it could follow could hinder their political career or affect their personal interests or those of their constituencies. When the local private industry engaged in basic research in Mexico offered a feasible project for the promotion of agricultural modern biotech, [the project] was shot down immediately based on the argument that “national sovereignty was being affected.” It seems as if some policymakers do not want to pass—or even ponder—any proposal coming from the [local or international] private sector; it appears as if they would rather have proposals exclusively developed by or coming from the local public sector. In my view, this is quite the opposite of promotion, inducing negative effects—ranging from low incentives for private investment to a drought in research coming from the private sector—affecting areas closely associated to the private industry and the development of the country in general.

From her observation it is easier pointing out the roots of some of the elements encouraging a disconnection between the public and private sectors as well as grasping how simple it is for discussions on policies for new technologies to become entangled within political whirlwinds.

Other areas of the system—like those addressing economics and education—will become more involved and play more active roles in decision-making processes when norms and standards for specific products and services are established and new areas of knowledge coming from modern biotech become formalized and introduced into the national education curricula in the

near future. At the present time, the secretariat of economics does have an important role when dealing with trade issues associated to modern biotech-derived products —mostly when these come in the form of products and services— and has a key role in intellectual property rights. Through the Mexican Industrial Property Institute, IMPI localized within its jurisdiction, the secretariat of economics is in charge of reviewing and issuing all modern biotech-related patents nationally. The foreign affairs secretariat —which ratifies all international treaties— and the secretariat of treasury also play less essential roles within the system.

Funding Sources

The majority of scientific research in modern biotech conducted in public institutions in Mexico is possible due to resources coming from CONACyT. As a central government body it makes federal funding available for basic and applied research projects at the national, state, and local levels, and serves also as a link between projects in need of resources and other private and public institutions that can provide them. The Council also manages a series of sector-specific funds aimed at making resources available for particular projects and for individual researchers who are members of the System of National Researchers, SNI. On the Council's system operation, actor M3-R pointed out that:

[Resources are made available to individual researchers] based on parameters like: number of publications and impact of these, previous projects, etc. In 2007 around 13,7000 researchers from a wide range of levels and sectors were currently accessing these funds by acquiring membership to the SNI, this number, however, barely reaches 0.7% of the economically active population of the country, missing the council's goal of reaching at least 15,000 by the end of the decade.

In his view, this particular process displays a considerable weakness particularly affecting the approval and funding of modern biotech projects:

A researcher applying for funding (in addition to requiring membership in the SNI) needs to disclose the line and depth of her research when submitting proposals for consideration. Ad hoc committees composed by other SNI members with congruent expertise, some which oftentimes have conflicting interests with the applicants and the projects, then evaluate these. As a result, a number of viable projects are turned down.

Accessing resources from some of the most recent sector-oriented funds established by the Council appear to be less rigid offering a wide range of options for new researchers and institutions within the National Scientific and Technological Industries and Institutions Network, RENIECyT. These funds are more oriented towards applied research and to promoting a research culture among new graduates with little or no expertise in proposal development and independent research. Additional sources of public funding for basic research come directly from state and municipal science and technology councils and federal and local secretariats, which offer limited funding aimed at more specific areas of local interest.

A number of public and private universities also engage in basic research activities often taking advantage of these sector-specific funds. Yet, most of these projects are perceived by high-ranking scientists within the SNI as “less rigorous” than those being conducted by more experienced applicants. On this actor M3-R commented:

These activities allow future researchers to acquire experience and methodological structure that may allow them to comply with the (Council's) standards at some point in the future. [At the university level] funding for research also comes from the education secretariat, which makes resources available for less formal forms of research and for projects not intended for global circulation aiming at completing more short-term academic goals, like honor thesis or class projects.

Regarding the government's total investment in basic research the expert mentioned that two presidential terms (12 years) ago the percentage allocated for basic research was 0.70 of the GDP being down to 0.35% in 2007. He continued by stating that:

Although the science and technology law originally required that the federal government invested at least 1% of the GDP in basic research, an ambiguous addendum was recently passed in congress to modify its text in order to make this percentage just a suggestion—a tendency—and not a requirement. Furthermore, if we compare this tentative investment percentage to that of other similar-size economies of Latin America—like Chile—we become aware that Mexico is lagging behind; these indeed have reached investment levels of at least 1%, not to say other developed countries—like Germany or the United States—which have reached investment levels between 2 to 4% of their GDPs. The biggest problem, however, is a lack of both political will and direction in these areas; while laws pretend to further promote investment in research, there is no way of knowing exactly what and how much the government is really willing to compromise. It has become fully discretionary and [the amounts of funding] change each time the government representatives change.

From his perspective, four specific and objective policies in Mexico are needed in order to achieve those levels of public investment: science, biotechnology, biosafety, and intellectual property, making sure these are clearly connected to each other and to a general science policy beyond the one already existing. In his words:

This central science policy has to be written in non-equivocal language, clearly defining the yearly levels of public investment to be allotted for basic research as well as stating how much these funds will increase over time. Not until a policy stating this is drafted— one going beyond governmental terms— will Mexico see a constant flow of resources or a well-structured national research system. This, however, does not mean there are no qualified scientists conducting high-level research in this country; their research and results are mostly exceptions to the rule.

Actor M11-G also stated that the vast majority of research in Mexico is funded by the public sector through its multiple education and research institutions, being CONACyT the largest and most structured source:

Basic research mostly takes place within the public universities and institutes, and it is possible due to federal funding (from CONACyT) and—in a lesser way—to their own resources. In general, research is rarely conducted within private universities; the private sector at this level is not really involved in research in Mexico. It becomes evident that research mostly takes place in the campuses of national and state universities (the National Autonomous University, UNAM; the National Polytechnic Institute, IPN, etc.); research is also conducted—at a less significant capacity—within the research institutes and organisms of or dependant of the federal secretariats. Most research on processes and applications in agricultural biotech and genomics takes place at the National Institute for Research in Agriculture, Forestry, and Fishery, INIFAP, within the agriculture secretariat. Other institutions like the Post-graduate College, the Autonomous University of *Chapingo*, and the Veterinary Medicine Faculty within the UNAM, target modern biotech and genomics research in veterinary medicine, microbiology and other related areas.

With respect to the percentage of public investment in research he almost echoed the statement provided by M3-R saying that:

It is appalling to realize that investment in basic research does not account for more than 0.4% of the GDP when the current regulation states it should be at least 1%. We have witnessed the positive effects of increasing public investment in research and science and technology, S&T in countries of similar economic size—like Brazil, India, and Korea—where benefits are becoming more noticeable throughout their economies.

On resource allocation for basic research in public institutions and universities actor M1-P appeared being less enthusiastic stating that:

The research conducted in these institutions more often than not appears to be disconnected from the markets needs and wants; these [institutions] plan, design, and perform their research agendas based on their individual priorities, without actually exploring market opportunities, or by choosing convenient research topics to which access to public funding is easily obtained. This neither coincides with

nor it works in function of creating new markets and the benefits that stem from these.

The private sector's contribution to basic research appears to be quite limited unless when conducted within the facilities of large multinational or local industries. With few exceptions, public research centers or universities are elicited for projects or receive resources from the private sector for open-ended research.

On the private sector's contribution to basic research M10-R stated that:

Although private investors are beginning to show more interest in basic research projects, their contribution so far has been marginal, often exclusively targeting projects that are closer to completion, time at which resources are less vital. Private investment is traditionally made available for research projects in areas like medical and chemical biotech—like drug and therapy development and beverage proofing, respectively—. It is obvious that the higher levels of investment in these areas will not come exclusively from the public sector; there will be a need to work in tandem with the private sector in order to create schemes that strengthen, favor and increase the flow of private investment in these areas. These should aim at inducing the allocation of resources into less developed research areas and, ultimately, at helping create a considerable-size resource pool' that continues attracting further private investment.

An argument on why private investment has been so limited, provided by actor M7-P, is that the private sector needs to become more aware of technological applications—or research—that could aid in the betterment of their products and production processes. This awareness could then be used to induce more investment in specific areas helping create new markets for products and services.

The private industry currently engaged in the sector seems to be completely aware of what can be done and what not with modern biotech in Mexico. Actor M9-P added on this:

Regarding modern biotech, the private sector has said quite clearly what it wants to do and what it cannot do in Mexico. One of the

main reasons for this lack of both human capital and financial investment is due to a completely unarticulated regulatory framework for modern biotech, making investors rather engage in these activities abroad.

Although some companies have established state-of-the-art research center in southeast Mexico in his view such centers cannot engage directly in modern biotech activities due to flaws in the regulatory system:

Researchers using modern biotech developed a pest-resistant papaya in these facilities. They had the genetically modified plant within a greenhouse ready for its open-field tests and could not move forward in our research without doing so. However, due to the absence of adequate regulation, the product was never tested on the field and the project had to be terminated. According to the existing regulation at the time they could only engage in biological pest control research but not with the use of modern biotech, because there was no such thing as a field-testing permit for LGMOs.

This particular case was based on the argument that allowing the open-field testing of the genetically modified type of papaya could be too risky for the local papaya species, more so since Mexico is the center of origin for a particular type of papaya prevalent in that region. Today the Biosafety Law's by-laws or *Reglamento* establishes in its Article 16 the requirements and procedures to obtain open field-test permits which, in the view of actor M9-P, are still quite rough and draconian.

Another argument proposed to assure public investment and continuous research in modern biotech with applications in agriculture in Mexico is a further revision of the intellectual property rights dealing with the access to genetic resources. On this M9-P commented:

I believe that the current Biosafety Law should address IPRs more explicitly. So far it does in such a cursory way that it cannot guarantee that the rights of those researchers and investors involved in particular projects will fully be respected.

In quite a similar perspective, actor M6-N suggested that the absence of a concrete regulatory frame and a well coordinated policy on modern biotech has kept the private investors at the margins of these technologies, often confronting them with users and consumers:

What the industry requires is a strong position by the government in support of modern biotech. The moment when such a position is adopted —going beyond all political pressure from the various NGOs and left-wing politicians— the industry and private investment in biotech will thrive. This will allow investors to look at agriculture as an investment opportunity, guaranteeing that financial institutions —such as the government-run trusts for agriculture, FIRA, the shared-risk trust, FIRCO, the rural capitalization and investment fund, FOCIT, or the national support fund for *Solidaridad* enterprises, FONAES— will now be able to promote the use of genetically engineered seeds and processes. Without this assurance private investment and all industrial and production linkage will not be achieved in this country.

Other sources of funding available for basic and applied research in Mexico come from joint ventures between the public and private sectors as well as from international sources. The most relevant international initiative derives from the International Research and Development Cooperation Fund, FON-CICyT, which in the fall of 2008 allocated 20 million euros for basic research—including projects in modern biotech— in Mexico. The funding, managed through CONACyT, apportions resources provided by the EU (mostly coming from Spain, the United Kingdom and France) and Mexico on a 50-50 basis.

Some research centers located in Mexico engage in activities partially or entirely funded by international institutions. Such is the case of research conducted within the International Maize and Wheat Improvement Center, CIM-MYT, or those projects funded through the Inter-American Institute for Cooperation in Agriculture, IICA, or operating within the framework.

On the multiple schemes that bring the private and the public sectors together actor M9-P commented that the industry as investor works exclusively within the market framework mostly taking care of its own needs. These research schemes are usually based on the industry's particular necessities, aiming at linking basic research with development and production, also suggesting that most private basic research is conducted "in house." He described a particular case between the private industry and researchers from the UNAM:

There are large size companies, like Nestle, making funding available for public institutions engaged in basic research in Mexico. However, these companies engage in such activities with local institutions in a more 'altruistic' fashion than just for the need of results or to conduct vital long-term research; in some cases these engage in short-term projects —some of which last no longer than four to six months— with universities and research centers because the local branch requires secondary information in, say, lactose pathogens. The results coming from these local ventures are of moderate value since the research with real industrial value is being conducted in places like Switzerland or Germany.

Those institutions and researchers that require of them know little (or nothing at all) of these resource-providing institutions and entities. Figures serving as connectors between these actors come then into picture. On the specific institutions linking the public and private sector in Mexico M9-P suggested that, more than associations functioning as bridges between basic research and the industry, there are individuals looking for attractive projects. Most of these individuals have access to funds from public, private, and international sources ready to be invested. For him one of the problems these individuals face is the fact that there are not many attractive [basic research] projects. In his words sometimes it happens to be the case that resources are available but there are not interesting enough projects:

Many are the projects focused on areas that appeal little to the private investor —such as forestry— as opposed to those focusing on

areas with industrial application. There are not as many research projects as desired by the [private] sector, basically because in Mexico a business mentality is not encouraged.

The few examples of public-private joint venture funds offered by him were a number of funds managed by CONACYT and a couple of private or semi-private associations working in agricultural biotech.

Since the establishment of the Mexican Council for Sustainable Rural Development, CMDRS, the secretariat of agriculture began opening more towards public and private basic research institutions and producers associations including those in areas related to modern biotech. Actor M11-G expanded on this:

[Within the CMDRS] there is a specific office linking the secretariat with technology producing institutions, which uses government funds, resources from the public-private PRODUCE¹ trusts, and those from the National Research and Technology Transfer System for the Sustainable Rural Development, SNITT.² Additionally, various areas within the agriculture secretariat have sector-specific funds managed by CONACYT, that operate using federal resources from CONACYT itself and the PRODUCE foundations, allowing [the secretariat] to better attend priorities and to direct resources more tactically.

Venture capital as a source of funding for modern biotech (or any other area of research) is quite limited in Mexico. Generally, there are two clear types of

¹In 1996 when Mexico's *Programa de Alianza para el Campo* came into force, the *Produce* foundations were created in each state. These organizations are in charge of following all actions deriving for this research, evaluation and technology transfer program currently known as: *Programa de Soporte, en el marco del Componente de Investigación, Validación y Transferencia Tecnológica*. Each of these foundations funds research, evaluation and technology transfer projects in each state, with resources from the federal, state, and private producers from each state. The 32 *Fundaciones Produce* are grouped within a national coordination office, COFUPRO, which integrates offices from the five regions of the country with similar interests in agriculture, fishery, forestry, aquaculture and livestock. Its actions are to develop a permanent strategy on technological innovation in order to promote and keep the competitiveness of the local production chains at the regional levels (COFUPRO, 2011).

²The National Research and Technology Transfer System for the Sustainable Rural Development, SNITT is an auxiliary body to the Inter-secretarial Commission for Sustainable Rural Development. The system's main role is to delineate a strategy allowing a permanent generation of innovation, technological transfer, and innovation to achieve and maintain the competitiveness of the rural sector (SNITT, 2011).

private investors engaged in basic research investment activities in biotech: individual venture capitalists —like those previously described as having a market idea but no investment expertise in these areas— and large corporations —like Monsanto and Dupont— with full expertise and a complete portfolio of pre-developed biotech products. In the view of actor M2-G there is a clear difference between these two types of investors:

The local venture capitalist has a short-term view targeting a particular product with the objective of accessing a high investment return rate —which impacts local basic research briefly— while the latter has a more structured and rooted view of the particular products it wants to market and has conducted most of its research abroad.

These views not only confirm that the vast majority of basic research projects in modern biotech take place within public institutions mostly funded by resources also coming from the public sector, but also that applied research and venture projects are generally conducted within large corporations that can absorb any loss. With few exceptions, basic research projects conducted within public institutions and research centers receive support from private investors. Furthermore, institutions linking basic research activities with potential private venture capitals are clearly absent within both the overall NSI and the local MBTS, heavily curtailing the prospect of creating new markets from innovation.

Research and Human Capital Formation

With respect to research and human capital formation CONACyT also plays a pivotal role in this framework. By law, it establishes and coordinates a series of funds (joint and sector-specific, international cooperation, and institutional) designed to support R&D and innovation activities, projects, as well as human capital formation and the consolidation of research groups and centers. A considerable percentage of the high-end research and specialized human capital

formation associated to modern biotech takes place within the network of research institutions ascribed to the council's Public Research Center System. The system is composed by 27 R&D+i institutions located throughout the country and organized in three areas depending on their scope: 10 in the natural and exact sciences; 8 in the social sciences and humanities; 8 more specializing in technological development and innovation; and one in post-graduate funding. In particular 7 of these centers address topics related to modern biotech: the Food and Development Research Center, CIAD; the Northwestern Biological Research Center, CIBNOR; Scientific Research and Higher Education Center of *Ensenada*, CICESE; Scientific Research Center of *Yucatan*, CICY; the Ecology Institute, INECOL; the Potosinian Scientific Research Institute, IPICYT; and the Technology and Design Support Research Center of the State of *Jalisco*, CIATEJ. CONACyT also coordinates the SNI —network composed of 14,000 renowned local researchers— whose objective is promoting a culture of excellence in scientific research in Mexico. Issuing membership to Mexican researchers of renowned trajectory, the SNI offers additional incentives to those scientists engaged in academic work and research as well as assists —through a series of *ad hoc* committees formed by its members— evaluating the efficiency and quality of the research in Mexico.

The net of public universities, research centers and professional and academic associations also have a fundamental position in this institutional framework. Most members of CONACyT's RENIECyT —research centers like the National Autonomous University's Biotech Institute, iBt-UNAM, the National Polytechnic Institute's Advanced Research and Studies Center, CINVESTAV-IPN, and its Genomic Biotech Center, CBG— also engage in producing the most modern biotech-related research and human capital locally.

Associations of academics of the caliber of the Mexican Academy of Sciences, AMC, also participate in setting research and human capital formation policy and standards at the national level. Particularly, the AMC—a non-profit association of regional and state researchers and scholars— plays two key roles in this institutional network; first, it aims at converging the views of an intricate network of scientists and professionals on modern biotech-related issues; and, second, through a multidisciplinary biotech committee composed by various of its experts, it serves as political and regulatory advisor for the federal government when it needs to define policies and standards. Through these instruments the AMC helped outline the current central regulations on the management of GMOs and have produced a series of important documents offering recommendations on how to consolidate modern biotech in Mexico.

Most higher education institutions, both public and private, engaged in human capital and labor hand formation in modern biotech are found within the National Association of Universities and Higher Education Institutions, ANUIES. The association is composed by 154 institutions throughout the 32 states and follows a series of strategic actions that range from teacher's training programs, industry and higher-education linkages, professional development support programs, long-distance learning, and evaluation certification, and accreditation of higher-education institutions. While part of the professional human capital formation and member of ANUIES, most private universities and research centers engaged in modern biotech human capital formation play less central roles within this network. To some extent, not having a solid system to produce research and human capital formation in modern biotech coming from private universities is yet another deficiency of the system. The local private higher education sector—highly oriented towards the business-side of ed-

ucation and research— has traditionally remained at the margin of basic and applied research in general as witnessed by actor M10-R:

Basic research is mostly being conducted within the public universities and institutes. In general terms, research [in modern biotech] is almost never conducted within private universities. The private sector —at the higher-education level— is not really involved in research activities in Mexico, let alone in modern biotech.

Some private universities, however, are developing a legitimate interest in areas related to modern biotech, like genomics, and bio-informatics, and agricultural biotech due in part to what some actors consider as “appropriate market conditions” for individuals with these type of skills. There are a growing number of private universities of the caliber of the Technological Institute of Monterrey, ITESM —one of the most respected and academically rigorous higher education institutes in Mexico— now offering various degrees related to these New Life Sciences, NLS areas in many of its campuses. These few cases, along with increasing yearly enrollment rates in these areas, display more awareness of modern biotech’s relevance locally. For some actors like M8-N and M9-P, there is a need to begin thinking about creating the jobs these graduates will be ready for in the near future. Actor M8-N suggests:

At this point in time the higher education system in Mexico is developing a network of researchers and professionals at various levels (bachelors, masters, doctorate), creating a critical mass of knowledge [and human capital] that might help develop the next generation of biotech-derived products and services. Yet, opportunities for them are not being created at the same pace.

Adding to this effect is also the fact that the majority of large research centers and universities —either public or private— offering specialization in modern biotech-related areas are mostly in or near larger urban areas as accounted by actor M11-G:

It also becomes evident that research is highly concentrated in the large urban areas where the main campuses of the national universities are located (the UNAM, IPN, and most state universities). Though some of their research centers and a number of research institutes and organisms attached to federal secretariats are situated in more rural regions, the majority of scientific activities conducted within these is much less significant in size and relevance than those being produced in centers near or within larger urban areas.

Although most of these research and human capital formation institutions are indeed localized in high-density urban areas, the levels of coordination between them is extremely low or simply not existing. Furthermore, this effect may be promoting the atomization of research populations in such areas and, consequently, forcing individuals in rural regions seeking to engage in these activities to migrate into larger urban centers. Moreover, there are no immediate signs of initiatives emanating from the public sector promoting the formation of clusters or inducing regional coordination between the major modern biotech research centers at the levels observed in Spain nor the establishment of regional networks linking such rural research centers with more urban-located ones.

The absence of a general policy aiming at establishing connection and coordination between research institutions is for some actors considered as an additional defect of the local R&D system affecting the development of modern biotech. Such lack is considered by some as having greatly eroded the possibility of defining and establishing more solid conduits to connect the public and private sectors, especially in this multidisciplinary area of the natural sciences. As actor M6-N states, this is a central system's flaw that has kept the private sector from taking a more active role in the promotion of modern biotech locally:

Channels aiming at linking public basic research with private development are the least developed within the system; there are no institutional channels in place to do so. The local and international private industries doing modern biotech in the country develop their own plans of action from scratch according to their particular ne-

cessities and without consulting anyone locally. These conduct all research “in house” and oftentimes abroad and —with very few exceptions— never solicit or look forward to connecting with research being performed within local research centers.

While the federal government does not actively promote plans that advance clustering into scientific parks or regions, one such a scheme at a national level comes from the private sector in the form of the Mexican Biotechnology and Bioengineering Society, SMBB. Although not exclusively focusing on modern biotech, the non-public institution definitely has a preponderant role in the advancement of this technology and a solid status in the general institutional system. The organization —grouping professionals and students of sciences related to modern biotech in Mexico— has among its various functions promoting scientific and productive sector linkage, technology transfer between and within public and private sectors, human capital formation, and helping in the design of regulations affecting areas of knowledge associated to modern biotech.

At the state level, however, there seems to be a more vivid initiative towards cluster formation and sector linkage. In the mid-western state of Jalisco the *Bio-cluster de Occidente* is one of the first of its kind in Mexico, association composed by basic and applied research institutions as well as by the local industrial sectors in areas of pharmaceuticals, veterinary medicine, and agricultural products. So far, its technology transfer efforts aimed at business starts-ups have created a few local small businesses. Another example can be found in the northern state of Nuevo León where the 25-member “Northeast Bio-Cluster” has managed to include key academic institutions like the Universities of Nuevo León, Monterrey and Morelos, and the private ITESM. Public sector participation is represented by CONACyT, the Secretariat of Education and Monterrey’s International City of Knowledge, and other local industry representatives. The focus of this Northeastern bio-cluster is to further develop R&D and foster part-

nerships between government and industry at the regional level. Yet another initiative along the same lines is the Mexican Life Sciences Alliance, formed by the two previously-mentioned clusters as well as CINVESTAV-Irapuato, and the UNAM's iBt. The central objective of this initiative is bringing together the four frontmost regions in the country as represented by four states —Nuevo León, Jalisco, Guanajuato, and Morelos— where initiatives aiming at developing cutting-edge innovation in areas of the life science-related have emerged. By joining forces across a national network, the alliance also aims at providing a large array of technologies and services to the global biotechnology market. The alliance has also managed to develop a strategic partnership with the University of California, San Diego, benefiting from its expertise in tech transfer and coordinated research initiatives. This initiative has yet to display results and by no means is comparable to the efforts witnessed in Spain.

Playing a central role within the existing system and also a key representative from the private sector is the civil organization *AgroBio Mexico*. Although targeting exclusively agricultural biotechnology, this association of large multinationals collaborates in policy making representing the industry, promoting sector linkage, and aiming at creating a positive environment for the advancement of agriculture modern biotech in Mexico. As part of its basic research promotion activities it recently established a prestigious and nationally recognized yearly award for basic research in agricultural biotechnology in Mexico. However, the organization has often been portrayed as lobbyist for its multinational associates before both the executive and legislative branches influencing on decisions dealing with the regulation of agricultural modern biotech. This perception has added hurdles to the establishment of links between public research and large private industry projects as corroborated by the view of actor

M9-P:

When the discussions over the biosafety bill took place before congress, some of the top researchers [within public biotech institutes] in Mexico —scientists deemed as central figures in basic research in modern biotech and a prominent advocates of agricultural biotechnology— were always sure of stating during these meetings that, although in favor of the technology and convinced of its safety, their researches were not funded in any way by the private industry, as implying that the views and results they expressed were not distorted in anyway by the interests of the private sector. This feeling still permeates the scientific community doing research in modern biotech in Mexico, as if being associates with projects funded by the private sector —especially large multinationals— could somehow hinder your scientific reputation.

Still, companies like Monsanto, Syngenta, Dupont, Bayer, Dow, Novartis, and the local Savia —most members of *AgroBio Mexico*— are often the only promoters of large and expensive cutting-edge basic research projects in agricultural biotech in Mexico and originators of several collaboration agreements with local public research centers.

Views regarding what additional institutional actors or representatives of these should be part of this system are contrasting. All interviewed actors operating within more technical institutions considered limiting participation for non-experts and associations of these when defining the terms of reference and guidelines for highly technical areas —like biosafety or risk assessment. Conversely, others representing the industry suggested that user and consumer associations (less technical actors) should play more central roles in defining policies and guidelines aimed at reducing possible negative externalities from modern biotech products. Lastly, actors closer to the agriculture sector recommended the inclusion of representatives from the diverse producer and distributor organizations in the setting of guidelines and standards for production and distribution of modern biotech-derived agricultural products.

2.2.3 Spain

Actors, Networks, and Infrastructure

I now turn my focus to the analysis of Spain's NSI and MBTS institutional frameworks. Being a member of the EU and due to its organization in regions and Autonomous Communities, the institutional framework of its NSI and MBTS is quite complex.³ However, Spain's intricate institutional framework for the advancement of modern biotech from the public perspective is somehow similar to that of Mexico, in that it is mainly headed by both the central R&D institutional body—the newly created Ministry of Science and Innovation as chief of science policy—and an inter-ministerial commission regulating most activities with GMOs. Also composed by organisms whose jurisdiction range from continental to regional and district, this intricate system has in recent years been the subject of intensive institutional revamping. One of the most significant changes has been the establishment in 2008 of the Ministry of Science and Innovation, MICINN. The new structure now concentrates all governmental R&D efforts within a single structure and took over the roles of institutions and areas within other ministries previously engaged in the promotion of R&D and innovation like the Science and Technology Inter-ministerial Commission and part of the Ministry of Education and Science. Now being the single authority in charge of defining S&T national policy, it also became the “single window” for most R&D-related projects requiring funding from the central government. Among its central roles are applying the current national S&T Law, developing the National Research, Development and Innovation Plan, PNI&D+and managing and coordinating all public research organisms. Through its secretariats

³Although I address Spain's NSI and MBTS at the national level, I mostly concentrate this analysis on the two most modern biotech-prominent regions of Cataluña and Madrid.

and divisions the ministry manages both national and international R&D and innovation programs operating throughout Spain and harmonizes these with regional and local policies.

In 2003 Spain established the Inter-ministerial Council for GMOs, CIOMG, a collegiate organism part of the central administration whose main role—in contrast to that of Mexico's CIBIOGEM—is authorizing the commercialization of GMOs or products containing these; so as all pre-commercialization deliberate release trials and trade (import and export) of such organisms or products containing them. Also within its authority is the confined use and deliberate release of GMOs and LGMOs for the production of human and animal medical products; as well as approving the deliberate release of these within the national research program frame and of those activities associated to the inscription of such organisms into the commercial varieties registry.

The council—ascribed to the Ministry of Environment, Agriculture and Fisheries, MMA—is chaired by the MMA's environmental quality assessment director and composed as follows: One representative from the Ministry of Interior, MI; two from the MMA; three from the Ministry of Health and Social Policy, MSC; one from the Ministry of Economics and Treasury, MEH; one from Industry, Tourism, and Commerce, MITYC; and one from the Ministry of Science and Innovation, MICINN.

The National Biosafety Commission, NBC also a collegiate organism localized within the MMA, works closely with the CIOMG by informing the general public about the permits issued and requested for the confined use, voluntary liberation, and commercialization of GMOs. Also Chaired by the MMA's environmental quality assessment director, the commission is assembled by members of the MICINN, MSC, MITYC, and MI. Also members of this commission

are a group of experts directly appointed by the collegiate members, a group of specialized experts, and representatives from the health, agriculture, environmental protection, and research sectors within the Autonomous Communities.

In other areas, the MSC, and its analogous Autonomous Community authorities regulate medicines for human and veterinary use derived from modern biotech processes in coordination with the European Medicines Agency, EMA. In tandem with the European Food Safety Agency, EFSA, the MSC, along with the MMA, supervise all industrial biotech. Intellectual and industrial property is protected by the European Patents Office, EPO, while at the local level biotech-related inventions—including gene sequences—is enforced by the Spain's Patents and Trademarks Office, OEPM. The Community Plant Variety Office, CPVO, on the other hand, supervises plant varieties.

In particular, the Spanish Medicine and Sanitary Products Agency, AGEMED, within the MSC supervises pharmaceuticals, medicines, and other product for human health use. Environmental related issues are addressed by the European Environment Agency, EEA and the MMA. At the Autonomous Community level, the Catalan Agency of Food Safety, CAFS—which polices over topics related to GMOs and animal cloning—and Madrid's local Sanitary Service, SSM also engage in these activities. On this sanitary framework actor S1-P commented:

The scheme works adequately for the safety and innocuousness assessment of biotech-derived medications; however, it lacks a section devoted to promote the advancement of biopharma in general. Over the past years the European biopharma has not been immune to the product drought faced globally by the sector. Aware of some of the main issues curtailing its expansion, [the private sector] took a more pro-active role in policymaking and planning by co-founding with the EU an ambitious continental project labeled the Innovative Medicine Initiative, IMI. The initiative—part of the European Technology Platforms—focuses on reviewing every stage of the discovery and development processes, as well as within the clinical and

post-market trials, in order to come up with more adequate plans and policies to stimulate the sector's expansion.⁴ More specifically, the initiative looks closely at ways to improve safety, efficacy, reduce costs, and increase speed production of drugs —many of which are developed using modern biotech. To accomplish the initiative's goals, experts working within its framework rely on state-of-the-art techniques and processes like bioinformatics, advanced lab training, biomarker development, and many more doing an unbelievable assortment of actions to boost the sector being done at very large scale.

Particularly, the Fundación Genoma España —a government-run organization whose leading trustee is the MICINN, and whose central focus is technology, innovation, and entrepreneurship transfer in areas of biotechnology to the business sector— has played an important role in designing the guidelines and funding allocation principles of the Strategic Action Program for modern biotech found within the National Research, Development and Technological Innovation Plan.⁵ In the opinion of actor S5-G:

⁴The 7th Research Framework Programme, FP7 identifies Joint Technology Initiatives, JTIs as a means to support transnational cooperation in areas where R&D development can contribute to continental competitiveness and quality of life. More specifically, the JTIs are proposed as instruments to implement the strategic research agendas of a limited number of European technology platforms. The Innovative Medicine Initiative, IMI is one of the six initiatives identified in the FP7 "Cooperation" Specific Programme with the objective of reinvigorating the European Biopharmaceuticals industry. The main challenges identified by the industry are: 1) Insufficient R&D investment; 2) Technological complexity; and 3) Research in Europe being too fragmented and being located elsewhere. To tackle these challenges, the platform developed a multi-annual plan which identified principal research bottlenecks affecting the biopharmaceutical R&D process and sets forth recommendations to overcome these by focusing on research in four areas: a) Difficulty in predicting safety; b) Difficulty in predicting efficacy; c) Poor knowledge management; and d) Gaps in education and training. The platform was launched during the 6th Framework Research Programme developed under the lead of pharmaceuticals industry, involving all stakeholder groups (academia, represented by universities and other public research institutions; biopharmaceutical companies and small and medium enterprises, SMEs; healthcare providers and clinical centers; regulators and patient organizations). In 2009 the IMI priorities stood on two pillars: 1) Efficacy —targeting areas like: cancer, infectious diseases and inflammation chronic immune mediated diseases; and 2) Knowledge management —focusing on standardization, free access, interoperability and exchange of data relevant for drug discovery and development, including databases for drug and disease models and small molecules and a frame for access and exchange of clinical and healthcare data (EC, 2011a; IMI, 2011)

⁵The MSC, MMA and MITYC as well as the regional governments of Navarre and Andalusia also provide resources to the foundation. Various other local organizations collaborate with *Genoma España* to fully implement mechanisms and approaches that promote the advancement of modern biotech. Among these are: ADER —the economic development agency for La Rioja

Genoma España has played a pivotal role in the design and organization of many of the consultative actions through which actor groups —scientists, medial practitioners, industry representatives, and members of society— exchange ideas that have helped shape the policy principles behind R&D in modern biotech. Although the foundation is considered a small-size institution highly dependent on both governmental and non-governmental patrons, it is regarded as quite influential within the design process of instruments and strategies to assist promoting this and other related areas (genomics, bioinformatics, biosafety, sector linkage, etc.). It is one of the few dedicated exclusively to the advancement of this sector in Spain.

Although ascribed to the MICINN, it has a degree of autonomy that gives it more mobility and access to areas than some exclusively public institutions as mentioned by the same expert:

Being in contact with so many different organizations interested in the use of biotechnology, without being exclusively affiliated with one in particular, allows it to have a more thorough view of the sector, while also being of more assistance to the national and regional governments.

While many agree that basic research in public centers appears as being fairly funded, there is still much to do for innovation. In the perspective of actor S9-P:

[With respect to modern biotech] the public sector's will is enormous; politicians may change and plans may vary, but there is always common agreement on the importance of biotech and its need of subvention. Yet, the government cannot do it all; there seems to be a need to engage more actively [as private sector] in actions that create the growth-inducing environments for the business and finance components of innovation in the sector.

region; Agencia IDEA —the agency for innovation and development of Andalusia; the Spanish association of bio-enterprises, ASEBIO; Barcelona Activa —the development agency for the city council of Barcelona; BIOANCES —the Spanish association for European business and innovation centers; BioCat —the bioregion of Catalonia; Fundación OPTI —the observatory for industrial technology foresight; the Spanish institute for foreign trade; the national agency for attracting foreign investment to Spain; the economic development agency for Madrid; the Canary Island agency for economic development; the Spanish society for biochemistry and molecular biology; and the Vita-Aidelos project, among others (Genóma España, 2009).

In a similar tone, actor S3-R suggested that there is still a need for programs that induce the local industry's involvement in basic research planning:

Although government's efforts to link these two sectors are moving in the same direction, there is still much to do to connect basic research conducted within the organization of public institutes and universities system with the needs and wants of the industry. One of the main reasons for this, however, is the fact that the [local] industry has limited knowledge and understanding of the currently existing channels available to do so.

At the regional level, both Cataluña and Madrid —along with Valencia, Andalucía, and Pas Vasco— have engaged in developing innovative promotion and managerial schemes for the local advancement of modern biotech known as Bioregions. An important part of the regional modern biotech network, many policies operating at that level emanate from within these novel institutions. Cataluña's pioneering Bioregion —BioCat— originated primarily from the existing sector's collective initiative later endorsed by the Catalan government, as accounted by actor S7-G:

The concept —which initiated within the region— stems from a collective awareness about the importance of creating a formal biotech sector for Cataluña. The EU guidelines —which promoted an environment favoring the establishment of similar Bioregions throughout Europe— also encouraged the idea. Yet, one of the most important factors allowing this project to consolidate was the fact that numerous key actors within the local sector, who not only understood its potential but were also able to read what was happening throughout the continent regarding the future of biotech, had the ability to translate all this into the decision-makers' language, making the initiative appealing and plausible for them.

In her opinion, most of these ideas came from within the Barcelona Research Park, PCB, where several stakeholders —most which are still part of the sector's regional and national networks— were able to generate the sufficient synergy and necessary environments for it to germinate.

In spite of all local efforts, its establishment and initial operation were not necessarily smooth. Although the Bioregion was formally established in 2006, it was not until 2008 when it actually became fully functional and began making its significance evident. The many political changes the country was going through at the time of its conception, along with an initial executive management not aware of the economic and social realities of the region, made its first year-and-a-half of operation less than productive. Restructuring and further planning helped make multiple programs and projects from which the regional sector now benefits possible. Designing these new policies requires going through various stages, as explained by actor S7-G:

First, stakeholders engaged in regional research to identify the needs of the overall sector; then came up with a series of possible ways to tackle such deficiencies; and, last, they made formal recommendations to the different levels of government acting within the region.

Being these institutions and their network of rather recent establishment, most of their policies have yet to be translated into quantifiable results that can later be properly assessed and verified systematically. At the time of this interview there were already a series of strategic guidelines in place coming from BioCat as well as a number of additional formal proposals about to be presented before policymaking authorities for consideration within the local budget plans and legislation. Expert S7-G added:

At this point, we do not know if these new recommendations will become part of the regional or national policies, but am sure these will help advancing the sector.

Although the BioCat concept mostly arose from the academic, research, and private sectors—and can be considered the umbrella from which most public and private modern biotech initiatives hang in Cataluña—the decision for its establishment was entirely made by the regional government (being the region's

ministries of health, presidency, economics, and universities permanent members of its board of directors). Yet, simply by reviewing in detail its composition, the leverage it has acquired over policymaking and planning in Cataluña's modern biotech sector becomes quite evident.⁶

In the words of actor S5-G:

Among the central entities [within the Bioregion] are science parks, like the Barcelona Biomedical Research Park, PRBB —which has promoted the formation of highly skilled and competitive research groups —and the pioneering PCB— that not only hosts several top high-tech scientific platforms in Europe but also an operative and highly successful industry incubator. In particular, this science park displays the three central elements —research, infrastructure, and incubator— deemed as necessary to connect basic research with development and innovation in novel areas of research like modern biotech and genomics.

These Bioregions have induced throughout Spain the creation of multiple public-private initiatives as well as established the parameters for “friendly” competition among these in order to attract both public and private funding, human capital, and other resources. Many will be the initiatives from the local governments emanating from these regional clusters.

At an even more localized level are plans to link the development of industrial clusters with urban renovation and economic growth. A particular example at the city level is the *22@Barcelona* district, which transformed an area of nearly 200 hectares within the old industrial area of *Poblenou* into what acknowledges as being a high-quality environment for working, living and learning.” The project — considered one of the most ambitious of its class in Europe — aims at concentrating knowledge-based activities while creating urban, economic and social refurbishment. Although no specific project or company associated with

⁶BioCat is composed by 12 science parks —nine of which are devoted exclusively to biomedical and agri-food R&D activities; a network of 145 research centers of excellence, with 400 research groups in the life sciences; an R&D plus i budget that accounts for 1.44% of Spain's GDP and state-of-the-art research support infrastructures, among other elements (BioCat, 2009).

modern biotech composes the cluster yet, many developments — including several emanating from the nearby PRBB — are planning on moving within the district as declared by actor S4-R:

The PRBB is closely working with *22@Barcelona* to launch a modern biotech area based on projects emanating from this and other regional scientific parks. At this point, [the park] is no longer looking to expand its scientist base within its facilities; rather, the current expansion stages aim at establishing a basic research/private industry connection in Cataluña by extending its operations within multi-sector clusters like the near-by *22@Barcelona*.

Many of these regional initiatives derive from a necessity to depart from rigid and centralized structures —especially those affecting hiring and project selection processes— highly predominant within both the public universities and the local research centers, commented actor S8-R:

Breaking away from traditional structures, these new configurations facilitate accessing funding and issuing more expedited decisions on hiring and research projects. One of the benefits of this goes hand-in-hand with the inclusion of Spain in the various EU programs which have allowed researchers from all over the globe to become part of these regional centers in benefit of the local human capital. In my view, when you find yourself working with some of the best researchers worldwide, your quality as researcher increases. Furthermore, these schemes also facilitate the flow of information and reduce the time and red tape required to access it.

For him this also allowed further and timelier coordination with other regional centers working in these areas within or outside Spain:

Some equipment acquired by these Centers requires highly specialized expertise for its operation; for this reason the timely hiring of experts required is key for specific projects. More so because these instruments become obsolete at a faster pace, which considerably reduces the time to create the required expertise in-house.

At the moment of the interview he estimated that at least 30% of non-Spanish researchers —mostly coming from other EU countries, the U.S. and South America— were group leaders within the Center.

Finally for the case of BioCat, one less structured segment within the Bioregion is the association of hospitals, which just recently began organizing groups targeting specific areas of interest. As actor S7-G pointed out:

There are basically no novel institutions targeting these associations, assisting them in their research and prioritization efforts. Many are still the gaps in need of filling in order to attach this sector to the BioCat network. Yet, there is no doubt of their need for instruments that allow a systematic engagement of patient groups in the policy and planning processes of new pharmaceuticals and therapies deriving from modern biotech processes. Such schemes will not only allow the formation of stronger links between research at the university and scientific park level and the various levels within health care sector, but also facilitate designing more inclusive bottom-to-top policies.

Additionally, the region also has a conglomerate of bio-industries within the association *Catalonia Bio*, which actively engages in public policy making and sector linkage activities associated to the business and industry sectors in the region. As part of the sector-boosting efforts, additional initiatives emanating from BioCat promote and support start-up companies and mid-size existing ones by providing services such as: business plan writing, project planning and access to funding within the EU's Framework Programme for Research and Technological Development, FP7 (now at its 7th installment) structure, specialized training and access to innovation.⁷ Some of these recent policy initiatives suggest establishing an alternative stock exchange market exclusively for start-up firms and spin-off firms, as well as endorsing the central government's initiative to allow research-intensive start-up companies as Young Innovative

⁷The 7th European Framework Programme groups all EU research-related initiatives under a common roof. Along with a recently created Competitiveness and Innovation Framework Programme, Education and Training programmes, and Structural and Cohesion Funds for regional convergence and competitiveness, FP7 is aimed at helping to put into effect one of the EU's main goals of increasing the potential for economic growth and of strengthening European competitiveness by investing in knowledge, innovation and human capital. It is also a key pillar for the European Research Area, ERA (EC, 2011a).

Company Status, YICs ⁸ in order for these to gain easier access to particular types of funding. As a result of the latest policies about 250 companies working within the bioregion are now considered to be associated with either biotech or biopharma. BioCat also estimates that at least 60 of these target biotech exclusively, while about 120 are partly dedicated or just associated to biotech by using biotech or providing services for the biotech industry. Among those fully engaged in biotech, nearly 65% target medical research, splitting up their efforts between drug development and diagnostics at an almost 3:1 ratio.

Madrid's bioregion is also formed by a rich network of academic, research, and industrial centers. Geographically being the hub for Spain's central government, the cluster is composed by various Ministries of the regional government, biotech companies, public and private research centers, hospitals and universities. Madrid also has both a Regional GMO Control Office and a Regional Biosafety Commission, which supervises the application of all regulation relative to these types of organisms. In particular, the region is considered the leader in academic and research activities —generating 31.1% of the national scientific publications in biosciences and a yearly research investment in these areas of the vicinity of 400 million euros.

Among the numerous institutions located within the region are some within the National Research Council, CSIC —like the National Biotechnology Center and the Biological Research Center; Clinical research centers like the *Carlos III* Health Institute and the *Ramón y Cajal* University Hospital; the National Insti-

⁸According to the European Association for Bioindustries, EUROPABIO, a young innovative company must: 1) Spend at least 15% of resources on R&D; and 2) Be less than 15 years old. The main fiscal measures from the YIC scheme are: 1) Provide incentives for companies by a) Reducing social costs (social security, unemployment and pensions) by 100% for the first 15 years; and b) Not taxing revenues for the first 3 profitable years, 50% reduction over the next 5 years and 35% reduction over the next 7 years. 2) Provide incentives for investors by a) Not taxing capital gains on shares or stock options that have been held for a minimum of 3 years (EUROPABIO, 2007).

tute for Agrarian and Food Research and Technology, *INIA*, targeting agricultural biotech; and the *Complutense* and *Autonoma* Universities and Polytechnic institutes engaged in basic research in biotech. Further, Madrid also has scientific park mainly composed by the initiatives of the two previously mentioned universities and supported by CSIC, Spain's Environmental and Technological Research Center, CIEMAT, the local chamber of commerce, *Banco Santander*, and both the city and district governments.

The previously mentioned *Fundación Genoma España*, now depending directly from the Ministry of Science and Innovation, is also located within the perimeter of this extensive bioregion. However, a fundamental difference between Madrid's bioregion and BioCat is its closeness to the central government giving the impression of having less autonomy. Actor S2-N expanded on this:

Most of the actors composing Madrid's Bioregion are highly dependent on the ministries; although their decision-making and operative guideline design processes is completely autonomous, all final decisions are passed through and negotiated with the national Ministries. Ultimately, these still have a high hand in the biotech policy-making process in Spain.

The arrangement of enterprises associated with modern biotech and the new life sciences within Madrid's bioregion is also highly dense; mainly two of the most influential assemblages in the sector in Spain —ASEBIO and Madrid's Region Association of Biotechnology Companies, *BIOMADRID*— are located within this frame. In particular, ASEBIO operates more like an association of enterprises bringing together an array of institutions undertaking activities related to biotechnology throughout Spain —such as universities, other foundations, and technology and research centers— within its umbrella. Since 1999, the association has served as a meeting point for such actors, working closely with the various levels of government to promote the expansion of the sector. Its existence is mostly due in part to the fact that it belongs to and receives support

from EUROPABIO, and its membership to wider-scope Spanish Confederation of Business Organizations. On the influence the association has on policymaking and the closeness of this bioregion with the central government, actor S5-G mentioned that:

ASEBIO also has a predominant role within the policymaking process in science and biotech in Spain. In fact, its previous president is now Minister of Science and Innovation, while the President of *Grupo Zeltia* took over as chief executive officer.

On the other hand, *BIOMADRID* is a biotech company association working towards promoting the sector within the Autonomous Community. Its central objectives are also establishing more sophisticated communication channels between the multiple social and economic agents involved in biotech and related areas —like bioinformatics, clinical genetics, agricultural biotech, etc. Thus far, the association has 53 members, most of which fall within the SME status and devote a large part of their resources to R&D activities.

As in the case of Mexico, no initiatives emanating from the central Spanish government encouraged the creation of these regional biotech clusters. Yet, various recent central government measures encouraging coordination and collaboration between the national ministries and the elements composing the Bioregions are beginning to shape up.

At the continental level the European Federation of Biotechnology, EFB whose central office is located in Barcelona, is one of the most influential institutional policymaking institutions targeting biotechnology closely working within Spain. The EFB is a non-for-profit federation of national biotechnology associations, universities, research institutes, biotech companies and individuals working in the field aiming at promoting biotechnology throughout Europe and the globe. Through its 13 regional branch offices in Europe it supports activities in the various areas of biotechnology promoting research and innovation

as well as the safe and sustainable use of biotech. As commented by actor S6-N its composition is quite complex and has an influential voice over policymaking and science promotion throughout Europe:

Currently the EFB has 225 Institutional members from across Europe and over 6,000 personal members from 56 countries, most of which are scientists. It essentially represents the voice of science in biotechnology in Europe. Although the association has limited funding, it does have a relatively influential voice at the policymaking process throughout the continent. In recent years the EFB has impacted changes on small but influential directives like those relative to limiting the amount of ownership in a company any public sector employee can have. This overturned the requirement that university professors could not have more than 10% of any company associated with the products of their research, a requirement that turns many a researcher away from the idea of starting biotech companies in Europe.

At the time of the interview actor S6-N suggested that the establishment of an association of bioregions —along with the existing regional industry and academic clusters— could help create even more leverage for policymaking:

A cluster [of bioregions] could help joining forces in the design of more adequate communication and participation channels, since many of the topics related to the development of products derived from biotech — animal testing, field release, biosafety, etc. — are still quite controversial and need to be addressed in a more collective way.

It becomes evident that the level of coordination in policymaking and institutional operation of these is quite intricate not only in Spain but throughout the EU. Such levels of cooperation and coordination are clearly absent in Mexico or even North America.

Funding Sources

At the EU level, the European Commission established the European Research Council, ERC, to support researcher-driven frontier research and to define the

strategies and methodologies that stimulate scientific excellence in Europe. Through its executive agency the ERC implements and applies these in the management and operations of its \$7.5 billion Euro budget (2007-2013) for activities within the legal context of the FP7, including those related to modern biotech under the *IDEAS* specific programme (EC, 2011a). Since 2007 all funds for research coming from the central government (including those for modern biotech) are managed through a “single window” system within the newly created Ministry of Science and Innovation. Before the establishment of this scheme funds for modern biotech were assigned to individual projects and plans through the various ministries and by the *Fundación Genoma España*. On this, actor S9-P stated that:

Authorities supervising scientific and technological development in Spain were highly dispersed throughout the ministries making their service provision quite inefficient. The levels of bureaucratic burden and the red tape required to access resources made applying for research funding too complex a task. Before these changes anyone applying for federal funding—whether for a new bridge in a remote region or for a small modern biotech research project—required going through a long bureaucratic process involving various ministries and regulatory offices. The process has now become much more efficient and fluent.

Over the past decade public funding for modern biotechnology in the form of governmental subsidies has displayed a considerable expansion—increasing almost 330% from the year 2000 benchmark level—reaching an investment of 507 million euros by 2008. Such growth implies a yearly average investment expansion of 22% in research, development and innovation projects, and infrastructure in modern biotech. Allocation decisions are now based on the priorities and strategic areas of science as defined within the National Research, Development and Technological Innovation Plan, within which modern biotech has its own strategic action program. On the other hand, public credits for innovation

and infrastructure in modern biotech research reached a maximum of 116 million euros in 2007, only to decrease to 95 million by 2008. Reduction that is due in part attributed to the termination of the Scientific Research Promotion Program, PROFIT in the year 2007. Overall, the total public investment in biotech projects (subsidies plus credits) in Spain reached 602 million euros.

Funding for research and development for business related modern biotech projects—in addition to that coming from *Genoma España*— comes from the Centre for the Development of Industrial Technology, CDTI. The Centre serves as a public organization within the Ministry of Science and Innovation whose role is bridging the research-industry gap and aiding in technology transfer and cooperation within Spanish companies and between these and international enterprises.⁹ Through the National Strategic Technical Research Consortia Program, CENIT—which allocated 200 million Euros per program only in the year 2009—the Centre promotes R&D+i business projects and facilitates technology transfer in modern biotech. As actor S3-R stated:

The program echoes that of the European Union for general R&D+i projects; it now allows accessing funds at levels not previously seen in Spain (between 20 to 50 million Euros per project).

However, the program has a fundamental shortcoming; one of its main principles requires that at least 25% of these funds allotted go towards basic research conducted within public research centers throughout the lifetime of the project. On this he mentioned:

The issue arising from this requirement is the difficulty to determine a clean-cut investment percentage for basic research in public

⁹The Centre, formed by over 250 high-end professionals and researchers, with headquarters in Madrid is composed by a network of offices and representatives in over 10 countries of Europe, Asia and America. The center is governed by private Law in its relation to third parties, allowing more flexibility in its supporting tech-transfer roles. It provides access to its own funds and facilitates the access to those of third parties or other private institutions (including those emanating from the European Union) for both national and international research, development, and innovation projects conducted by Spanish researchers (CDTI, 2011).

centers that applies to all projects at every stage. This percentage varies greatly based on each project's necessities. For example: some projects initially require investing 80% of the funding provided to basic research and only about 10% at their final stages. As part of the industry sector companies have expressed their concerns and have proposed changes to the program's rule. Furthermore, the sector believes there is a need to create more awareness from behalf of the industry about projects currently being conducted within these centers. Otherwise the industry —instead of having incentives to create partnerships— simply leases the services offered by these public research centers and pays for these below market optimal levels.

Various researchers believe that the overall investment resources available for R&D+i are still too dependent on public resources. In the view of actor S4-R:

While the percentage of private investment in research and development in some countries within the E.U is between 60% and 70%, in Spain barely reaches 50%. If the private industry is not drawn to play a more active role, the country will never reach the [investment] levels expected from any top-tier EU member.

In his opinion, investment should be more focused on what he defined as the 'second step' where basic research is channeled into applications and into technology transfer, leaving investment in applied research mostly in the hands of the private sector.

On other issues, he suggested that the biggest setback of engaging in applied research from within a public research center is having to go through all the red tape and bureaucratic burden associated to it:

A researcher engaged in a project requiring a state-of-the-art device needs to jump numerous bureaucratic hurdles and ultimately wait for a public auction to be conducted in order to engage in research. By the time he gets the equipment, the project is either outdated or the investors who elicited have taken [the project] somewhere else.

From the standpoint of actor S8-R, the central reason for this disconnection is because the industry —due to its for-profit nature— rarely engages in basic research. Channeling most of its resources to applied research or development,

it forces public centers and universities engaged in basic research to compete against each other to access public subvention:

The real problem is not that centers like [the genomic research center] dependent too of public funding; the real issue is that the availability of these funds is subject to political wavering. In other words, funding is never guaranteed; nobody really knows what the levels of funding will be the in upcoming government cycle, making long and mid-term planning almost an impossible task.

In his view designing policies that allow keeping S&T programs unaffected from political change and, thus, allowing for long-term planning is fundamental for the advancement of local and regional basic research:

Genomics and epidemiology-related projects —which oftentimes require between half or a complete decade of constant flow of resources— are frequently put aside due to this imperfection, while those that do go on constantly face resource shortages and default deadlines. This also provides more insight on why the industry avoids investing their resources on basic research; incomplete projects display few or no results.

Yet, Spain has indeed witnessed a growth in investment since the establishment of the Bioregions network, RBR.¹⁰ These associations — mostly composed by regional industries and research centers — have promoted an increase of all sources of funding, especially those coming from the private sector. A clear example is the recently formed Madrid Biocluster, which in 2008 —its first year of operation— committed 62 million euros, action without precedents in that region. On the other hand, the recent establishment of public ‘soft money’ allocating agencies is not viewed as the best of ideas for some actors, adding to the negative effects of politics behind public financial resource allocation for modern biotech. On this, actor S1-P stated that:

¹⁰Composed by five regional clusters (Madrid, Cataluña, Valencia, Pas Vasco, and Andalucía), the Bioregion network, RBR serves as a platform for cooperation and coordination among regions as well as a forum for best practices. Other areas like: Canarias, Extremadura, Aragn, Navarra, and Baleares will join the network in the near future (BioCat, 2009).

These agencies or newly formed areas within existing ones are supposedly helping the sector by creating investment funds composed by —say— two or three million euros for their use in modern biotech projects. Following a political agenda, these funds are then invested in a significant number of start-up companies, stretching the resources as much as possible. Basically what is happening is that these agencies give the start-ups enough funding to make absolutely nothing. The policy behind these actions is to create the illusion of remarkable results; since many companies are previously reviewed and granted funds, these resources are believed to be efficiently allocated and, thus, benefiting the sector. However, due to the scarcity of the resources ultimately granted to each company or start-up (and to their high dependency on public funding), most of these companies never get to reach their fully developed stages, let alone produce a single marketable item or service. Five years later, none of these will probably still be around. This issue, however, is not exclusive to Spain. This is happening all over Europe and in the US as well. In my opinion, one way to steer away from [this model] is to promote the rise of professional investors, the kind of individuals having carried interests (such as the dividends a venture capital investor gets when a project becomes successful) within specific projects. The logic behind this is that, if these are to make money, they are going to be making a lot of it, and that is what is going to motivate them. As for their salary [as professional venture capital investors], it is fair to say that —in the short term— these would make less than what they would do if they were investment bankers. Yet, they would have to work much less and, by the end of the cycle (when the fund closes and pays its returns to investors), there is a high probability they become millionaires over night.

Private investment is perceived by all interviewed researchers as a much more efficient and easier to access source of funding than that coming from the public sector. Yet, in the opinion of actor S4-R, accessing funds from the private sector has both benefits and risks:

Although funding is granted faster and with fewer complications, there is always a risk that the investor —usually a company or association of these— decides to terminate the project prematurely. This usually happens to be the case when the project is within a specific timeline too hard to meet by an outsourced research team or simply because there is no longer invested interests in the project. These funds are in function of the investor's time frame

In Spain most of the private investments flowing into modern biotech comes from corporate groups putting together specialized funds and searching for specific projects. Following this point actor S1-P mentioned that:

In Spain this is a fairly new model, which has demonstrated success throughout Europe. Another [model] becoming highly popular is the one that encourages Spanish business people to come back to their homeland, especially those who are engaged in creating this types of VC funds abroad and have a track record, so they can come back and raise local funds and persuade some of their partners abroad to also do so.

This last type, however, is just starting to become more popular as a number of funds for modern biotech are beginning to shape. As an example he mentioned the case of a Swiss-Catalan biotech entrepreneur who is putting together various biotech funds for Spain, which will end up being the first real series of specialized biotech funds created by a national locally:

Everyone will dispute the fact that these are indeed the first funds targeting these areas. However, neither someone with such a successfully international track record in the biotech investment, nor someone with such a structured series of funds have ever engaged in putting together a series of funds and investing locally. The most significant difference between these funds and other S&T-oriented funds is that a committee truly conscious of the realities of the biotech sector professionally manages these.

Some local industries have also taken advantages of the stock market and raised funds directly by issuing stock. In the words of actor S9-P this has been the case for a number of subsidiaries derived from the local pharmaceuticals giant Zeltia requiring funding for basic research:

Research funding for its subsidiaries engaged in modern biotech projects—especially those using oceanic biological resources—come from within the company through various public stock offerings.

One of the most widespread joint venture funding models seen throughout Europe is the consortium composed by the public, research, and corporate sectors. These associations join efforts by putting together a steering committee

and a series of funds to support basic research projects in various strategic areas—including modern biotech. A number of large successful projects like the PCB and the PRBB— fall within this category. As previously mentioned, these initiatives have had trouble bringing back some of Spain’s prime investors who are still working abroad, making it difficult to create locally run private funds for these specific modern biotech-related areas. Yet, initiatives moving in that direction are clearly beginning to take shape.

The public-private consortium scheme emanates from the previously mentioned EU’s Framework Programme for Research and Technological Development, FP7, which among its main objectives puts forward the notion of focusing on results and coordinating efforts under a single structure. Most funding for these consortiums comes precisely from the Programme’s multiple research-oriented funds and other more modest sources as corroborated by actor S1-P:

The EFB foundation also engages in providing funding for small modern biotech projects—either those being conducted within these consortiums or independently—as well as in matching these projects with additional sources of private funding.

In his view the agency’s resources are quite limited, providing an average of 200,000 euros to four or five projects per year—observation supporting the previously expressed views suggesting that a number of newly created organizations oftentimes provide limited funding for new companies. Yet, he suggested that the agency also engages in other more significant roles than simply providing direct funding, which can be considered of more assistance for starting-up companies, such as connecting projects with other fund sources, as well as helping gaining access to information and creating research collaboration among various regional centers. From the perspective of other specialists national and regional investment and growth levels in R&D+i also require of the private sector’s cooperation; actor S4-R suggested this:

If 'attachment free' funding coming from the private sector was as available as that coming from the public sector, basic research in modern biotech would be at a different stage of development. Today, most of the financial resources coming from the private sector are either allocated on projects in which the funding party has a stake (which are usually short-term and small in size) or have been (or will be) disbursed under highly rigid legal terms. To induce better benefit and information sharing will require more sophisticated tax incentives and benefit-sharing schemes, among other structures, designed jointly by the industry and the government.

Other international initiatives aiming at increasing resources for research in modern biotech emanate from a series of strategic support actions —such as round tables and multi-sector participatory exercises— in which issues on how to create incentives for investment growth in early stage modern biotech research throughout Europe are addressed. On this actor S1-P stated that:

A series of recommendations and suggestions for decision makers derive from many of these exercises —activities directly funded by the EU commission— which then become part of local or regional policies. Yet, the most significant contribution stemming from these initiatives are the various entrepreneurship and business-related programs aiming at researchers and scientists; these coach them on how to address VC investors, present programs before them, and raise capital for their individual projects. Basically, these teach them how to become entrepreneurs.

For him, another essential element of these internationally funded initiatives are the numerous fairs and conventions where researchers, scientists and VC investors, and other actors, network and engage in various activities to raise resources and promote collaboration:

These events aim at putting together multiple actors from within the multidisciplinary spectrum of modern biotech for a brief period of time. As these became more popular and began displaying more positive results, the private sector's interests on these also began growing. Many of the now established initiatives started as small 200,000 euros projects aiming at organizing two or three small venues over a three-to-four year time period. Today, there is not a

single month of the year when at least one of these events focusing on biotech is not scheduled somewhere in Europe —many of which are hosted by Spain.

An innovative funding scheme emanating from the international arena currently being explored in Spain is the previously mentioned Young Innovative Company Status, YICs. The special category (initiative of the European Association of Bioindustries, EuropaBio), allows research-intensive start-ups to access specific state aid through tax incentives as explained by expert S1-P:

Although, in theory, some of these companies may be considered within the SMB category, in practice, these share more traits with larger companies due to their size and resource investment levels. The YICs idea tries to take into account multiple traits generally overseen by more conventional start-up funding schemes (such as the resource ratio differential between early and later stages or the number of years these companies have been established for). This has improved the overall fiscal treatments applied throughout Europe for these types of companies; today there are a number of EU fiscal policies allowing the reimbursement of investments in R&D up to a certain percentage due in part to this initiative. Yet, neither every country is doing it, nor most companies know about this possibility. If more researchers knew about it, the number of start-ups would be by far larger than the current.

Although most of the R&D funding initiatives within the EU emanates from the previously mentioned FP7 funding is much more fragmented than in other parts of the world as corroborated by expert S1-P:

Funding granted at the European level comes from a series of framework programs of which numerous possible users oftentimes do not know about (or know of ways to gain access to). Moreover, the EU Commission oftentimes provides funding for break-through projects that never reach applied levels, unaware that they are shifting the central objectives of many of these programs from expanding investment in tech-transfer activities to promoting basic research funding.

International funding coming from other regional associations is quite limited, and has to be allocated strategically. Some organizations —like the European Federation of Biotechnology, EFB— provide significant input on where

funding for research in modern biotech coming from the various EU programmes should be allocated. On this, expert S6-N declared:

The EFB makes sure that important areas of biotech are not being excluded from funding; that funding is not exclusively poured into projects that —truthfully— can be considered as outdated; the federation also aims at assuring that the EU Commission becomes aware of the potential of certain areas of technology as well as creating an awareness of the funding opportunities for all its members, while also promoting their active involvement in participatory and networking processes.

Venture capital (VC) in modern biotech in Spain has displayed a somewhat inconsistent behavior over the past decade. From 2005 to 2008 the total VC investments reached 122 million euros, which represents a five-fold increase when compared to the investment levels accounted for the 2000 to 2004 period. Venture capital investment in biotech accounts for 1% of the total VC investments in Spain, while in the group of 15 most advanced countries within the EU (EU-15), it reached an average of 2.7%. It was only in 2006 —when various local biopharmaceuticals engaged in a series of VC investment operations— that the local average VC investment levels in biotech were above those of the EU-15, reaching 2.8%.

For a number of actors the reason why VC investment (and locally developed funds) for modern biotech is so scarce has to do with both, the improper application, and the lack of understanding of the current IPRs system. On this actor S4-R stated that:

Many of the local institutions and research centers turn their eyes to MIT or Stanford and think they can generate patents that license just as those coming from those institutions. However, they seem to overlook the fact that that, for each financially successful patent those institutions have, these also produced hundreds (that may or may not be licensed) which produce no substantial returns. Here is where the motivation —for both researchers and venture capitalists— begins curbing.

Adding to this problem is the lack of experienced patent law firms, as expressed by actor S1-P:

There is a shortage of firms fully understanding the sector's IPRs and patenting at the global level —the kind of firm that knows the sector so well that it does not have to redo the patent every three years. Additionally, these are not fully knowledgeable of licensing terms, oftentimes scaring away possible licensees and investors.

This apparently simple issue turns into a destructive cycle that has threaten to stall the growth of modern biotech sector throughout Spain and Europe. As explained by actor S1-P, this sequence consists of the following stages: a) a local research institution finally licenses a patent (or a number of these), which then become the basis of a spin-off or a start-off industry; b) these small companies attract initial local funding managing to stand afloat and move forward for a year or two, catching the attention of professional biotech VC investors; c) when these approach the company to determine if it is investment-worthy, these then realize that the terms of the licensing are not quite what they wanted to see (either because these are not clean enough, the percentages to the research unit are too high, the risk-sharing is not quite appropriate, etc.); and, finally, c) due to this, the company never reaches maturity and eventually disappears.

On other aspects related to VC investment, actor S9-P suggested that one of the mayor factors determining whether this type of investment will flow into new companies is the time that these take to consolidate. In her view the time these take to go from start-up to a mid-level industry is fundamental for attracting VC investment:

In the modern biotech sector, companies taking too long to consolidate or not engaging in mergers with other start-ups at the precise time often appear unattractive for venture capitalists. Furthermore, if the vast majority of these new companies within the biotech start-up network system stay too long at an embryonic stage, VC investors will remain skeptical of the entire system.

For most forms of resource investment, a solid venture capital system for modern biotech requires a fine balance between the benefits of the prospected outcomes, time to maturity, and a neat environment that provides sufficient guarantees that investors will actually see returns. In Spain (as in most of the Europe) this system has yet to be perfected.

Research and Human Capital Formation

As previously mentioned, the central figure promoting modern biotech and science in general in Spain is the newly revamped Ministry of Science and Innovation, MICINN. Through its secretariats and divisions, the ministry manages both national and international programs operating within Spain and coordinates these with regionally and locally developed policies. So as in Mexico, most basic research is produced at the various public research centers and foundations affixed to the ministries, being the *Genoma España* the most directly engaged in activities associated with modern biotech. Other entities partially engaged in modern biotech research projects are the previously mentioned Health Institute Carlos III; the National Agriculture and Food Research and Technology Institute, INIA; the Centre for the Development of Industrial Technology, CDTI; and the Energy, Environmental and Technological Research Center, CIEMAT. Public universities also operate as central agents of scientific promotion as well as producers of a large percentage of the local science. Additionally, most technology transfer offices, OTRIs, which advise scientists in areas like patenting and licensing as well as in scouting for resources for start-ups or spin-offs, are located within these.

Considered the most important public research organism is CSIC whose objectives of promoting, coordinating, developing, and diffusing multidisci-

plinary basic research encourage the advancement of basic research throughout Spain. Additionally, the center is the chief figure in human resource formation and allocation in all areas of basic research. Most of Spain's public research is conducted within its 126 research centers and 145-affiliated research units located throughout all Autonomous Communities and regions; numerous of which —like the National Biotechnology Center; the Agro-biotechnology Institute; and the Biomedicine and Biotechnology Institute of Cantabria; the Agro-genomics Research Center; the Cinegenetic Resources Research Institute— are directly engaged in biotech-related research.

The vast majority of these centers are located within the regions of Cataluña and Madrid, followed by both the Andalucía and Valencia. The concentration in these territories is mostly attributed to the development of successful programs within these regional research centers as well as to the successful policies to repatriate Spanish scientists currently working abroad. These have created alluring environments for local and international scientists engaged in basic research in these areas.

Spain has developed a quite sophisticated technology transfer scheme, of which the central instruments are the S&T parks and clusters and the network of the abovementioned OTRIs. These serve as connectors between basic research and the industry and have consistently helped bridging the gap between basic and applied research throughout Spain. Additional instruments supporting this linking venture are the multiple national and regional Technological Centers, CTs and the Supporting Innovation Centers, CAITs, which have the specific task of assisting the private sector in the application of basic knowledge for innovation, including that produced within the OPIs and scientific parks and clusters. Both CTs and CAITs now have achieved legal status through the Real

Decreto 2093/2008 and are part of a national registry and list, also created by the same legal instrument. Other more conventional instruments (targeted tax incentives, subsidies, platforms, etc.) are also part of the array of promotion tools available in Spain aiming at connecting sectors and bridging the gap between basic and applied research.

From within the scientific network there appears to be a notion that a number of these successful policies and plans (more specifically those that have derived into tangible projects) stemmed from initiatives and efforts of influential scientists, including those that have been contacted abroad and repatriated. In the view of S9-P:

During the 1990's a group of local scientists had the vision to engage in policy and planning through various initiatives aimed at bringing back some of Spain's most valuable human capital; one of the first successful cases was that of Mariano Barbacid —Spanish researcher whose work led to the isolation of the first human oncogene in the Spring of 1982— who spent over 20 years abroad before returning to Spain in 1998 to create and direct the National Cancer Research Center. Another case is that of the current director of the Barcelona Biomedical Research Park, PRBB —Jordi Camí Morell— whose initiative not only helped create the park and many of its research units —like the Centre for Genomic Regulation, CRG and the Centre for Regenerative Medicine, CMR— but also helped establishing the Health and Life Sciences Studies department within the *Pompeu Fabra* University in Barcelona. Furthermore, he developed a “Code of Good Scientific Practices” that has been adopted and followed by all scientists working within the PRBB's research centers since 2001.

In his opinion many of these initiatives were —in addition to the efforts of a particular scientist or a cluster of these— feasible due to the fact that Spain was able to access funds for infrastructure improvement coming from the EU at a time when these were vital. Yet, he suggests this has changed lately:

In recent years this has become less viable; by expanding its R&D+i sector Spain has reduced its standing as a recipient of such pro-infrastructure development funds, turning projects of the caliber of

the PRBB into much more difficult endeavors to consolidate. Now, promoting new initiatives requires—in addition to resources mostly generated locally—meticulous and structured planning and actions to coordinate all actors involved.

Presently, top-to-bottom plans emanating exclusively from the government are often received with skepticism by the scientific community and are more often than not considered as lacking the necessary depth. It has become more common to witness how commissions—led by local scientific leaders—engage in dialog with different levels of government and request advice from various interested actor-networks when looking forward to implement large-scale plans as suggested also by actor S9-P:

Politicians are less informed about the projects' objectives than any of the scientist or scientific leaders working within these, making them less capable of framing such initiatives. [For these projects to move forward], either we have to wait for politicians who are willing to learn, listen, and trust the views of experts—something that is highly improbable—or we engage in actions for better informing them about the sector—which is highly complicated. Efforts to better inform politicians should always be a priority within the agendas of these scientific commissions and the scientific parks behind them, something that could be accomplished more efficiently if these research centers established government-scientific community *liaison* offices that could perform such activities.

Since their first days these clusters have altered the ways science and government collaborate and interact also having new levels of influence in the way science-related policies are defined and established in both Spain and Europe. These have also allowed a more active role for institutions conventionally focused exclusively on scientific production and human capital formation (private research centers and universities) as well as for those scientists and experts working within these.

As explained by actor S9-P, these size projects require large government subvention during most of their initial stages. Nevertheless, he points out that for

many researchers this association has to evolve at the pace at least as fast as that at which these clusters develop otherwise government control nullifies their objective:

Recognizing when a cluster has reached a point where governmental intervention is not required as much as it was during its embryonic stages is of the utmost importance; not doing so could result in two distortions: too much political control over research being conducted within its multiple centers, and the use of the cluster for political purposes. Politicians more often than not care less about science as opposed to the tangible things emanating from these parks —like the number of jobs, patents or enterprises created— since these are easier to translate into their political platform and language.

On the other hand, for him these clusters are viewed as development agents actively participating in the advancement of yet additional social structures linked to scientific development, industrial processes, and policy-making:

These parks are not only at the forefront of research but are also ahead in areas like: new enterprise creation, definition and management of IPRs, innovative managerial processes, etc. Yet, in the particular case of the PRBB, although being fully aware that keeping up with these technologies is quite difficult, it looks forward to the next challenge; while others emulate or try imitating other successful models, [the PRBB] defines its own solutions, otherwise it would always be one step behind. The park has such long-term vision that at this point it has no intention of competing with clusters or regions more oriented towards finding applications for basic scientific discoveries; if it came up with something that can be turned into a product following the Boston model, it would be better-off making it available for them to develop; [the PRBB's] research teams are engaged in creating never-before-seen processes and developing new research techniques, not just trying to emulate some other model just because it appears as being more successful. They are looking forward to establish the basis for basic research processes and then target the connectors with development.

For many a scientist in the regions of Cataluña and Madrid various are the reasons why these novel structures can be considered as a great leap towards achieving a more efficient science and research production models. These

schemes have allowed Spain's research in biotech and the life science to reach international standards, providing more autonomy for local research and inducing the rise of novel research collaboration schemes. For actor S8-R, these structures have allowed for multiple research groups to form simultaneously—as opposed to inducing the formation of only a couple before their establishment. In addition to being competitive enough to stand out internationally, this has happened in a relatively short period of time and much more intensely than in many other countries in Europe. He continued by saying:

Although these groups could be pursuing completely different lines of research, these collaborate with each other through personnel and information sharing within the park. The most successful projects stemming from both the Cataluña and Madrid regional parks are those who have succeeded in cutting the red tape and have been able to hurdle through the bureaucratic obstacles mostly set by the Spanish university system and the CSIC as well as those that have timely adapted themselves to the impetuous changes of these technologies.

Yet, in the opinion of actor S1-P, these efforts can still be further fine-tuned:

The biggest downside of these regional efforts is their lack to attain sufficient resources from the private sector, especially for modern biotech. All efforts should be aiming at attracting investment and not just scientists; there is a need to keep in mind that research is turning resources into knowledge, while innovation is turning knowledge into resources. Although the levels of research being conducted within these centers has reached—or even surpassed—international levels of excellence, there is still a shortage of funding for projects, inducing researchers abroad to think twice before coming back home. However, this is not as salient as the scarcity of funding for innovation, which is what ultimately curtails the development of a more formal and structured biotechnology-based sector.

As also mentioned previously one of the most significant initiatives to reduce these effects is the Bioregions system operating throughout Spain.

2.2.4 Policy and Regulatory Frameworks

In this section I provide information on the nature and elements composing the political and regulatory frameworks of both Mexico and Spain R&D systems also looking into how its central actors —both public and private— interact and set the rules followed within these. Just as the previous sections, this part is complemented by the views of multiple individual actors supplying more information on the system's composition, politics, and links to international institutions assisting in its general performance and the formation of these environments.

2.2.5 Mexico

Regulation, Polices and Planning

There is a generally accepted notion among scientists that science is to be promoted not regulated. Furthermore, when aiming at balancing the advancement in research, the proper management of risks, and the economic implications deriving from new technologies, defining policy strategies and estimating their outcomes oftentimes goes beyond economic, scientific, or technological determination; politics, consequently, come into the picture playing a more determinant role in these actions. Regulation, in this context, displays distinctive national traits, making evident the different timings, priorities, forms, and stringency of interventions (Jasanoff, 2005). These protocols consider creating incentives and increasing the connectors that can induce an advancement of R&D and, thus, create suitable environments for the different competitive frameworks shaping potential technology markets to thrive.

Based on these premises an efficient structural framework for scientific ad-

vancement should be composed of a balanced mix of these elements. This somewhat describes the approach followed by the Mexican government for the setting and design of policies and regulations affecting modern biotech. In the current regulatory landscape, two are the central instruments affecting this technology: at the NSI level the Science and Technology Law, LCyT and The Biosafety of Genetically Modified Organisms Law, LBOGM, at the MBTS level. As a scientific activity modern biotech is promoted using the legal instruments defined within the former, and due to its direct association with biosafety, the latter mostly regulates basic and applied research and innovation activities with GMOs.

By and large, the scope of the central biosafety instrument focuses on three ambits: 1) GMO management, establishing permits, notifications, and authorizations systems as well as risk management procedures; 2) information management, establishing a national biosafety information service and a GMO registrar system; and 3) restricted area management, determining GMO-free zones and environmentally protected areas. In addition, this law makes two important adjustments to the previously existing framework; by establishing its operation rules within its body it gave legal character to the already existing CIBIO-GEM, and clarifies more the role of each of the secretariats directly dealing with biosafety, primarily those associated to agriculture, environment, and health sectors.

Yet, the feeling that this regulation is optimal is not universally shared throughout all sectors; to some of the actors within the biosafety realm interviewed, the regulatory instrument still does not properly clarify the roles of all sectors and —since it increased the regulatory burden— some are now the target of applicants' criticism —especially from those representing the scientific

and research sectors. On this actor M4-R suggested that:

The law still displays various loopholes, mostly regarding authority roles and operation rules. It is, however, a first step requiring various follow-up stages. And as any regulatory process, this framework has two sides; the applicants have almost as much responsibility [as authorities] in these processes; it is up to them to present complete and fully complying applications, which result in prompt approvals. All applications not complying with every single requirement —however trivial— established by this new law have to be declined. This shared responsibility also affects the timely advancement of this science. To some, this is exclusively [environmental authorities'] fault.

The novelty of these processes and, conversely, the applicants' lack of experience in complying with all regulatory requirements is often perceived as dampening the oftentimes timely-contingent life span of these researches and innovations. Yet, as witnessed in the previous sections, mechanisms such as specialized technology support offices, helping with filing procedures, and sector linkage processes, like creating clustering research and development where such specialized offices thrive (readily available in Spain), can help reduce or even reverse these effects.

On the importance of this instrument and the overregulatory burden it may represent the private sector's perspective actor M9-P suggests that:

Although the guidelines set [by the law] can be considered complex, it is easier having a regulation that you can later simplify, better, or update than not having one at all. More substance should have been given to the *Reglamento* and subsequent norms and standards than to the law itself. I have the notion that thick laws are harder to reform and slower adapting to changes than their by-laws. This regulation has precisely this disadvantage.

On other topics, the legal instrument steers away from regulating human genomics and any type of conventional biotechnology or even derivative products or processes —including pharmaceuticals— using GMOs as inputs. The management of these activities fall within the scope of either health or agriculture

regulation (or both) or to international treaties depending on the particular case. Additionally, it also does not regulate the access to genetic resources as well as the intellectual property behind biotechnological products and processes, delegating these activities to environmental and intellectual property rights regulations or also to international treaties on these areas to which Mexico adheres.

Deriving from the Biosafety Law is its *Reglamento* or by-laws. These describe in detail the requirements and procedures for permit and authorization issuing (including those for imports), and delineate the operation and composition of the internal review commissions for biosafety —outlining operation rules and guidelines— and the technical scientific committees helping in the permit and authorization review processes. Furthermore, these define the operation rules of the national biosafety information service and its registrar system as well as the guidelines to determine restricted areas and genetic diversity and origin centers. Moreover, these describe the management of lists for both authorized GMOs and permitted activities using these; set inspection and emergency principles and specify sanctions; and spell out a regime for the protection of local maize varieties.

On scientific promotion, and as mentioned earlier at the NSI level, this regulation states that the federal government —mainly through CONACyT— is in charge of promoting and strengthening scientific and technological research in modern biotechnology through the application of those guidelines defined within the Science and Technology Law. It also establishes that such actions shall take place through a series of policies and instruments oriented towards: 1) promoting research, development, and innovation projects; 2) human capital formation; and 3) the strengthening of university and research center infrastructure.

At a more general level, the Science and Technology Law confers CONACyT the responsibility of putting together a general science and technology council. This group is in charge of defining the policies and establishing the guidelines for the promotion of all publicly supported science activities in Mexico.¹¹ The law also states that every four years the council will define a Science and Technology Special Program, STSP, to implement these actions and strengthen the national S&T sector.¹² Serving as chief science and technology advisor to the executive and as central science policy planner, CONACyT is in charge of orchestrating and implementing all instruments defined within the Plan to promote the advancement of science, including those relative to modern biotech.

Modern biotech is also addressed within more sector-specific regulations. In agriculture, four regulations make reference to agricultural biotech, GMOs and biosafety: Plant Health; Seed Production, Certification and Trade; Organic Products; and Sustainable Rural Development laws. The Animal health Law and its newly enacted *Reglamento* oversee aspects of biotech associated to animal health and feed. Within the environmental protection realm, the General Environment and Ecological Balance Protection Law and its *Reglamento*, and the Forest Sus-

¹¹Article 5 of the Science and Technology Law establishes the role, reach, and composition of the general council. The permanent members of the council are: the President, nine state secretaries (foreign affairs, treasury, economics, energy, health, education, agriculture, environment, communications and transports), CONACyT's general director, the science and technology consultative forum coordinator, and the heads of the Mexican academy of sciences and the national universities and higher education institutions association. Three additional non-permanent members selected by the president—either from the science and technology consultative forum or independently from the scientific, technological, or productive sectors—serve also as active members with voice and voting faculties. The President has the faculty of inviting additional participants to the general council's sessions. These will have voice but no vote (EUM, 2002, 2010a).

¹²On June 12, 2009, a bill proposing a series of amendments to the Federal Science and Technology Law was passed by congress. These alterations basically revamp the science and technology protocol followed by Mexico, establishing policies to coordinate federal and local initiatives, as well as to link basic and applied research at any level of federalism with the productive sectors. Among many changes, these reforms amended its articles 21 and 22 relative to the design and implementation of the Science, Technology and Innovation Special Program, which includes topics on biotechnology and biosafety (EUM, 2009a).

tainable Development Law attend to topics related to biosafety and their possible environmental impact. When concerning human health, modern biotech is approached through five *Reglamentos* affecting the General Health Law: Products and Production Processes; Product and Services Sanitary Protection; Health Inputs; Publicity; and Research on Human Health. This last regulation sets the biosafety guidelines for research with recombinant DNA, aiming at reducing risks to human health or possible adverse environmental effects from it. These also specify the general guidelines for research and development of products and processes for human use, also affecting the outcomes of genetic engineering processes.

The Mexican Penal Code also addresses modern biotech allocating responsibility and specifying both monetary and punitive fines for faults to all the above-mentioned regulations dealing with the biosafety of GMOs generated through these techniques.

Within the latest version of the National Development Plan, PND 2007-2012 topics on biosafety of GMOs are cursory addressed as part of a series of strategic lines on the establishment of centers of origin and biodiversity protection from both an agricultural and environmental perspective. However, although these points introduce to national policy topics associated to modern biotech, their briefness and cursory nature gives the impression of not been proposed and written by up-to-date officials or scientists experts in these areas but instead by less informed politicians —or even private consultants. During one interview session this was pointed out to me by actor M12-R who stated that not including current regulatory actors in the policy defining processes —especially when drafting national policy plans— adds to feeling of low coordination often felt within modern biotech’s regulatory framework:

PROFEPA is aware of its institutional role beyond that defined

within the PND, more so when it comes to modern biotech's biosafety with respect to biodiversity protection. Yet, it is not too clear if its counterparts in charge of biosafety in agriculture and human health are as aware of theirs. If public officials active in these areas had written these policies, everyone would be well aware of their role.

Creating more awareness on policymakers through the involvement of scientists and developers as part of the advisory groups helping in the drafting of these national policies and plans addressing modern biotech is considered of great importance for the sector. From the perspective of actor M3-R:

[Scientists and developers] should participate more actively in the definition, establishment and application of biotech biosafety regulations. This would also help reducing the politics behind these processes as well as providing more public awareness on the direction towards which science is moving.

The success of scientific advisory groups within policymaking processes not only depends on the qualifications of the experts composing them and the objectivity of their views, but also on the unambiguous notion that any views offered are provided with total independence and completely scientifically-based. Especially when the subjects of discussion are considered politically volatile, scientific advisory bodies require being entirely autonomous and transparent to public scrutiny.

International Links

The international regulatory and technology policy landscapes also exert influence over the development and evolution of the Mexican biotech regulatory, policy and planning framework. On the regulatory side, rules and principles emanating from the multiple international organizations to which Mexico adheres (UN, WTO, NAFTA, EUFTA, WIPO, among other) affect the advancement

of modern biotech in areas like biosafety, intellectual property rights, and human health protection. These serve as reference guidelines for the design and setting of local rules and standards and the reshaping of the regulatory and institutional scenario. On the technology policy side, the quick advancement of information technologies at the international level has provided modern biotech with access to global tendencies and forums where these topics are discussed internationally, facilitating the expansion of these with areas relative to technology transfer and human capital formation. The influence that international regulatory frameworks exerts over the Mexican modern biotech regulatory landscape and the relative low maneuvering margin left for local policymakers is captured in the opinion of actor M2-G:

In a global world, local regulation attends to those international instruments to which a country adheres. Unfortunately, Mexico is more of a follower than a leader regarding international guidelines in these areas. Although having a considerable important voice and vote in several of these international [standard setting] forums, Mexican representatives usually end up abiding to other's decisions or yielding to specific group's pressure. Within these commissions our representatives more often than not take positions that do not reflect our national priorities.

The majority of international agreements addressing topics related to modern biotechnology to which Mexico adheres emanate from either the United Nations system or from the World Trade Organization structure; The Convention on Biological Diversity, derived from the UN Environment Program, UNEP is one of the central international guidelines on biodiversity protection. As a member party to the Convention, Mexico adheres also to the Cartagena Protocol on Biosafety. The protocol—considered an international agreement by the Mexican congress and therefore at the same status as a local law—establishes regulatory mechanisms for the trans-boundary movement of living genetically modified organisms, LGMOs and has highly influenced the guidelines set within the lo-

cal biosafety regulation. Through a system known as the Advance Informed Agreement, member countries have the capacity to deny access for commercial shipments possibly containing undisclosed LGMOs without incurring commercial sanctions. Through this mechanism the protocol promotes a 'precautionary approach' for environmental protection among member countries. However, this mechanism applies only within the network of protocol members, making it easy to incur in trade sanctions if applied to non-member parties. Furthermore, the protocol's text states that once it came into force—and in the absence of specific local regulation—all member countries were to apply its guidelines. This meant that the Protocol's guidelines would serve as temporary central biosafety regulation for the trans-boundary movement of LGMOs while each member country developed its particular set of guidelines.¹³ This point greatly influenced the timely drafting of many a national biosafety regulation—including Mexico's—as corroborated by the opinion of actor M3-R:

The international principles set by the Convention on Biological Diversity and its biosafety protocol created an avalanche of guideline and regulation drafting in Mexico that reached its pinnacle with the passing of the Biosafety Law in 2005. Since 1988, Mexico has been engaged in norms drafting, even establishing rules for the environmental release of experimental GMOs before many more industrialized nations did. Yet, the drafting of these guidelines created friction between the industry and the government; the former faced a series of shortcomings in the existing regulation impeding investment expansion, while the latter was still figuring out the appropriate risk reducing principles in needed of establishment.

¹³Due to the fact that the United States is Mexico's largest commercial partner and not a member of the protocol, developing alternative guidelines for the movement of these organisms became an issue of great importance requiring immediate addressing. On October 2003 a trilateral agreement between USA, Canada, and Mexico for the implementation of the protocol's Article 18.2(a) on the trans-boundary movement of living modified organisms intended for food, feed, and processing was signed, terminating the possibility of creating trade disputes. The document—setting the minimal standards and biosafety procedures that such commodity movements should follow—also serves as example of the influence that international links have over the biotech regulatory landscape in Mexico (Canada, 2011).

Another international area of relevance to local policy is that of sanitary measures related to food safety. On this, the *Codex Alimentarius*, emanating from the World Health Organization, puts forward a series of guidelines and principles on how to assess product innocuousness, including those guidelines for the labeling of products containing GMOs. Although not binding, these international guidelines have encouraged the drafting of a series of propositions and bills on this last topic, some still circulating within congress. These guidelines will continue influencing the current Mexican modern biotech landscape in the near future as applications from these technologies keep moving forward into the realm of consumer goods.

As for establishing links with international institutions, many are the local scientist and developers organizations that have developed these. The Inter-American Institute for Cooperation in Agriculture, IICA is considered one of the most influential international links promoting biotechnology currently operating in Mexico helping develop programs covering specific necessities as defined by the local users. The International Maize and Wheat Improvement Center, CIMMYT was also mentioned by several interviewed actors as having close links with local developers. The center—which emerged from a pilot program funded by the Mexican government and the Rockefeller Foundation—engages in cutting-edge research in both genetic engineering and genomics through its multiple research programs and units. Directed and composed by both local and international researchers, its genetic resources program, seeds inspection unit, applied biotechnology center, and germoplasm bank—among other units and programs—are considered top-notch within the Consultative Group on International Agricultural Research, CGIAR network. Lastly, within the frame of NAFTA is the North American Biotechnology Initiative, NABI serving as a

forum for the exchange of information in technical areas, such as technology transfer and previous experience sharing between Canada, the U.S. and Mexico.

2.2.6 Spain

Regulation, Policies and Planning

The current general regulation on S&T in Spain is the formerly mentioned Scientific Research and Development Promotion and General Coordination Law or *Ley 13/1986*. This regulation establishes the PNI&D+i as the State's programmatic instrument for research, development, and innovation. Required by law, the plan establishes all medium-term priorities, specifies the instruments to achieve these goals, and defines ways for its enforcement. Recently revamped in format and scope for the period 2008-2011, the plan is now divided into four strategic areas: 1) Knowledge and Capacity Building in S&T; 2) Cooperation in Development and Innovation; 3) Sectorial Development and Innovation; and, 4) Strategic Actions. In addition to these strategic actions and related plans the program follows a number of instrumental guidelines and national programs already existing at various state organizational levels —ranging from human resource formation to institutional strengthening and coordination.

The plan is further divided into five Strategic Action Programs, one of which is modern biotech, due to its multidisciplinary character. These five actions aim at transforming basic research into economic value-added processes, products, and services by concentrating all governmental R&D+i resources and instruments towards actions that encourage sector linkage.

Also at the programmatic level, the INGENIO 2010 initiative has served as a cornerstone for S&T in Spain. Through further expanding public resource

allocation the implementation of multiple strategic actions that aim at linking research and industry sectors, the initiative puts forward a set of guidelines for Spain to achieve its goal of converging its local R&D+i investment levels with those set by the EU.¹⁴

Along these lines, another instrument for the promotion of science is the National Science and Technology Strategy, ENCyT. This document puts forward the guidelines and central objectives that, from the views and perspectives of key actors within the national and regional systems of innovation, should determine the central public policies for S&T locally. Its current 2007-2015 version expands on efforts to implement the National Development Plans and the INGENIO 2010 initiative.

Almost at the same point in time when the initiative that created the new Ministry of Science and Innovation was proposed, a bill putting forward a new S&T law to replace the then current S&T law, *Ley 13/1986* was also introduced. By the end of 2009 the draft reached substantial consensus and successfully underwent a collective participatory process to obtain further views and com-

¹⁴The INGENIO 2010 program central objectives are: a) Increase the investment levels in R&D+i; b) Aim resources at strategic actions; c) Promote legal reform that encourages R&D+i activities; and d) Establish and implement a follow-up and policy review system. Additionally, its goals also are promoting regional/territorial coordination, reducing resource dispersion, increasing the effectiveness of public investment in R&D+i, and aim at reducing the intra-territorial investment deficits. Among the instruments and programs emanating from it are: 1) CONSOLIDER Program, offering funding for mid to long-term projects managed by large research networks in any scientific area; 2) RETICS and CIBER Projects, promoting the formation of stable research structures within the frame of the National Health and National Science and Technology Systems through funding for biomedicine and health sciences projects; 3) PLAN 13, which promotes the inclusion of local and foreign researchers within the National Science and Technology System; 4) Strategic Fund for Scientific and Technological Infrastructures, promoting the formation of research parks associated to universities or public research centers as well as equipment and infrastructure renewal; 5) CENIT Program, to stimulate coordination and collaboration between the government, industry, universities, research centers and scientific parks engaged in R&D+i projects; 6) *Torres Quevedo* Program, which facilitates the inclusion of public researchers into the private sector; 7) NEOTEC Fund, consisting in venture capital funds to help create start-ups and spin-offs; 8) AVANZA Plan, aiming at converging local IT capacity with that of the E.U.; 9) EUROINGENIO 2010 Program, aiming at gaining a higher returns percentage from funds provided by the E.U. through its VII European Union frame Program for R&D+i (MICINN, 2011a).

ments. According to several interviewed actors, numerous social agents —such as representatives from all Autonomous Communities, various actors speaking on behalf of scientific communities and associations, university representatives, and numerous independent experts and interested citizens— had the opportunity to offer their views and recommendations through such participatory exercises. Numerous of these proposed amendments were included in the complete an agreed text approved by the Council of Ministers before being sent to the Chamber of Deputies for its enactment as Law on 7 May 2010. This bill came into force on 12 May 2011 as *Ley 14/2011* derogating all provisions set by the *Ley 13/1986*. This regulation aims at strengthening the State's organizational and planning abilities as set by the current lay (which consist on the development and implementation of the central National Scientific Research and Technological Development Plan). It also puts forward a more dynamic S&T promotional system that considers: a) the Autonomous Communities' capacity to define R&D+i instruments, policies and funding schemes; b) Spain's full integration to the EU; c) the demand for more innovative administrative and funding schemes (through the establishment of a State Research Agency); d) the expansion of the local scientific community and the absence of a well defined science-oriented career path; and e) the Spanish S&T System's need for integration and full mobility within international schemes. It further puts forward the establishment of a Research Ethics Committee to monitor and issue recommendations on principles and best practices regarding scientific endeavor. Although modern biotech is not explicitly mentioned within its text, both the administrative and institutional schemes proposed in this new regulation will continue affecting its local development (MICINN, 2011b).

Ranging from Laws and Royal Decrees down to Orders and Communica-

tions, rules and regulations affecting modern biotech have a hierarchical degree in Spain, in a similar way to that followed by the EC. The central regulatory instrument in this area existing within Spain is the *Ley 9/2003*, which establishes the framework for the confined use, voluntary release and marketing of GMOs. The Law defines the role and composition of each of the institutional members within the authorization, review and supervision procedures, as well as the role played by the Autonomous Communities in each of these processes. It further specifies the guidelines for each of the three cases as well as the general norms regarding new risks, confidentiality and public communication, emergency situations, and labeling of products containing these organisms. Finally, it establishes authority fees as well as sanctions and policing systems.

The law's implementation is detailed within the *Real Decreto 178/2004*, which delineates the operation rules for the complete regulatory framework and establishes all biosafety and risk assessment/risk management procedures required to obtain authorization for each type of activity. The decree also both launches and provides legal character to the Inter-ministerial Council for GMOs and the National Biosafety Commission.

In the area of genetically modified seeds and plants the *Ley 30/2006*, relative to the treatment of seeds and greenhouse plants and fitogenetic resources, puts forward the rules for monitoring these type of organisms and establishes a registry for both plant varieties and seeds. Furthermore, it defines the requirements and procedures for their production and marketing and sets rules for the import and distribution as well as control and certification of these. It introduces guidelines for the access to genetic resources, as well as key specifications about how to gain access to these when used in research, betterment, and to promote sustainable use and conservation activities. Organizations and individuals outside

Spain requesting access to these resources will have to abide to the specifications set by the EU directives on this matter and will only be able to do so if their country or state have previously signed agreements with Spain on the transfer and exchange of these materials. Moreover, it reinforces the Autonomous Communities' faculty to define independent rules for the access to resources endemic to their regions. As for the receptors' responsibilities, the statute makes clear that these cannot claim intellectual property rights on any parts if such claim can restrict the access to these resources for agriculture and food uses, as found in their natural state (or as these were when access to these was granted to the patent filling party). Receptors cannot transfer these to third parties without explicit consent of the granting authorities, and are required to report every two years any application or discovery stemming from research and use of these resources (with the exception of strictly confidential information, as defined within international IPRs guidelines) for a period of twenty years. Lastly, those individuals or entities marketing products which incorporate genetic material derived from these resources are required to allow unrestricted access to such products to any individual or institution within Spain that intends to engage in further research and/or genetic betterment activities using these, also abiding to existing international IPRs guidelines.

Expanding on this topic, the *Ley 30/2006* establishes the National Program for the Sustained Protect and Collection of Genetic Resources for Agriculture and Food. Based on the principles defined within the international treaty of the same name, this program: a) promotes a responsible and appropriate use and protection of these resources; b) creates the National Collection Network, serving as data and seeds bank; and c) establishes the National Center for Genetic Resources, which serves as expert advice provider for regulatory authorities.

Detailing with the enforcement of this Law is the *Real Decreto 1891/2008*, which approves the *Reglamento* or rules for the authorization and registry of seeds and greenhouse plants producers and the rules for their inclusion within the National Producers Registry. These by-laws define the producer's classification as well as the operation rules these need to follow to achieve registration.¹⁵

On animal health the central regulation with implications on modern biotech is the *Ley 8/2003*. This regulation sets the parameters for disease prevention, control, and eradication as well as the guidelines for animal export/import practices. It sets a national emergency system and a network of laboratories engaged in research on disease prevention and the development of veterinary products. It further sets the rules for the production and commercialization of veterinary medicines and other zoo-sanitary products, as well as for feed products. Additional regulation on the authorization, marketing, and use of zoo-sanitary products is given by the *Real Decreto 488/2010*, which includes aspects of public safety of those veterinary products not regulated by the previously mentioned animal health Law. Lastly, the *Real Decreto 1201/2005*, sets guidelines for the protection of animals used in research; including those that are genetically modified or which are used in research using GMOs.

Medicines and sanitary products are regulated by the *Ley 29/2006*, on the guarantees and uses of medicines and sanitary products. This statute develops a general regulatory framework for medicine production, ranging from rules for basic manufacturing to traceability and labeling, as well as one for substances and materials used in these production processes. Advanced therapies based on

¹⁵Other regulations associated to vegetable and plants affecting modern biotech are the *Ley 3/2000*, establishing the regulatory framework for the protection of new vegetable varieties; the *Real Decreto 289/2003*, on the marketing of forestry reproductive materials; The *Reglamento* for the registry of commercial vegetable varieties; *Orden ARM/405/2009*, establishing the *Reglamento* that sets the technical rules for the control and certification of seeds for feed plants; the *Real Decreto 929/1995*, setting the technical rules for the control and certification of greenhouse fruit plants; and those setting specific rules for particular crops like corn, soy, potato, etc. (EC, 2011a).

modern biotech and those being produced with GMOs are also reviewed within these rules.

Defining the particulars of authorization, registry, and disbursement of industrially manufactured medications for human use—and addressing modern biotech outputs in a more direct way—is the *Real Decreto 1345/2007*. As a supplement to *Ley 29/2006*, this statute specifies the necessary steps required for sanitary products to reach commercialization, including those produced with GMOs. These rules establish the biosafety guidelines for medicines using or being produced with GMOs. Depending on their use and type, these products require environmental risk assessment before commercial authorization is granted. Further risk evaluation to estimate possible side effects of these organisms on the receptor individuals are compulsory in the cases when these are used to produce or are themselves part of human advanced therapy medications. The risk management procedures required by this decree rely heavily on the parameters set by the *Ley 9/2003* and *Real Decreto 178/2004*. Rules for the management of genetically modified animals, when these are the originators or carriers of genetic modification tissue, cells, or parts of these to be used for these therapies, also falls within the scope of this statute, complemented by the previously mentioned *Real Decreto 1201/2005*.

Veterinary medicines using GMOs as inputs or parts of these also fall within the framework of the *Ley 29/2006*. The particulars of their management are detailed within the *Real Decreto 1246/2008*, on the authorization, registry, and overview of industrially produced veterinary medicine and the *Real Decreto 109/1995*, on veterinary medications and general rules for veterinary medicines.

The main regulation on biomedical research is the *Ley 14/2007*, which lays down the principles and guidelines for biomedical research within Spain. It

addresses issues regarding human subject's informed decisions and the access/protection of private information; discrimination; traceability and medical biosafety procedures (including those with stem cells and any other type of embryonary cells and tissues); sets limits to research and procedures using genetic engineering techniques; and, establishes the Research Ethics Committees supervising these activities. Furthermore, it defines both the National Cellular Line Bank and the National Bio-bank Registry, to help manage the dissemination and use of human genetic resources. The statute, which has had great leverage in the promotion of the current basic research system, also puts forward multiple guidelines to help establish coordination between the National Health System and private medical and research institutions (public-private cooperation). Likewise, it defines guidelines for human capital formation in biomedical areas and the establishment of funding schemes for basic research.

Treatment of cells and tissues within biomedical research—including stem cells and any other type of cell that has been genetically modified or enhanced—is defined within two statutes: The *Real Decreto 1301/2006*, setting the quality and safety norms for the donation, access, evaluation, processing, preserving, storing, and distribution of cells and human tissue; and the *Real Decreto 65/2006*, that establishes the requirements for the import and export of biological samples. When engaging on clinical essays or any other type of research using GMOs, biosafety rules and other compulsory contentious procedures are further detailed by the Spanish Medicine and Sanitary Products Agency, based on principles set within both *Ley 9/2003* and *Real Decreto 178/2004*.¹⁶ Specifically

¹⁶Other regulations affecting GMOs associated with the production of medications and sanitary services, clinical studies and other pharmaceuticals are the *Real Decreto 824/2010*, regulating pharmaceutical laboratories, pharmaceutical input producers, and the international trade of medicines and research medications; *Real Decreto 223/2004*, providing guidelines for clinical essays with medicines; *Real Decreto 1277/2003*, establishing the general bases to authorize sanitary centers, services, and establishments; *Real Decreto 1591/2009*, regulating sanitary products; and *Orden SAS/3470/2009*, publishing the guidelines for observational post-authorization research of

sanctioning faults on human genetic manipulation is the *Ley 14/2006*, on assisted human reproduction techniques.

From the perspective of intellectual property modern biotech is addressed within the *Ley 10/2002*, which introduces to the current patent law (*Ley 11/1986*) rules for the access and deposit of biological material, guidelines on the scope and range of patentability, and terms for compulsory licensing. Echoing its EC counterpart, this regulation only fine-tunes the existing framework on IP and avoids creating a parallel framework exclusively for modern biotech discoveries. One additional regulation affecting IPRs is the *Real Decreto 55/2002*, on the exploitation and concession of inventions generated within the national research centers. This ruling establishes—much in a similar way to the Bayh-Dole act in the United States—how the rights over inventions (patents and other contracts regarding these) discovered within public research entities are designated and how capital returns emanating from these are distributed among these entities and the actual inventors. In general, the regulation establishes that the national research entities where these inventions took place can either retain or resign to the full entitlement of these rights. In the former case, any benefits emanating from these inventions will be divided one third for the institution, one third for the actual inventor or inventors, and the last third as decided by the institution's directive body. In the latter case the inventor(s) retain most of the rights, providing a free, non-exclusive, non-transferable license to the research center plus 20 percent of any capital returns deriving from these. Finally, this decree also establishes the rules for the case were these inventions were made within the frame of a contractual agreement or a collaboration agreement, cases where the guidelines are virtually the same as those followed when the research

human use medications; *Real Decreto 2070/1999*, regulating donation and clinical use of human organs and coordinating the territorial organ and tissue donation and transplant (FSS, 2011).

entity retains all rights.

Lastly, a recently proposed bill to define a Sustainable Economics Law has introduced a series of reforms with direct implications on the sector's growth capacity. The proposals, which have been well received by the industry—in particular by ASEBIO— puts forward a series of reforms that have an effect on: a) Public contracts, by suggesting new rules for these and for government procurement; b) Public-private collaboration and technology transfer, clearly delimiting rights over inventions developed using public resources; c) IPRs, by proposing—among other things—a reduction in filing costs and promoting communitarian filing procedures; d) Fiscal measures, by reducing red tape and facilitating investment at initial stages of research and; e) on Human capital formation, by increasing the level and quality of local modern biotech research personnel.

As mentioned previously, the Autonomous Communities can also define guidelines supplementing regulations set by both the EC and the Spanish central government. In general, few are the rules directly affecting modern biotech at these levels of federalism, and those existing only detail the supervision and control of activities regulated by state and continental laws, as well as define and issue the applicable sanctions in case of infringement. In Cataluña, the *Decreto 109/2000* sets a regulatory framework for the confined use and voluntary release of GM vegetables, while Madrid established it through its *Decreto 109/2000*, both a Regional GMO Control Office and a Regional Biosafety Commission. Additionally, the Autonomous Communities of Andalucía, Aragón, Asturias, Baleares, Castilla La Mancha, Castilla y León, Extremadura, Navarra, and Valencia also have developed local regulations regarding the use and application of GMOs.

International Links

The EC is the central pillar within the EU's regulatory framework with rights and obligations under international law and allowed to pass laws and adopt treaties.¹⁷ The central regulatory frame for the EU in R&D is the Council Regulation (EC) 723/2009 establishing the community legal framework for a European Research Infrastructure Consortium, ERIC. This framework was established to develop the European Research Area, as well as to promote competitiveness, a legal framework for this type of infrastructure, which will compensate for the absence of appropriate national or international regulations, when necessary.

As a member of the EU, Spain's policies and plans promoting the advancement of S&T (in general) and regulating modern biotech (in particular) are those set by the EC Commission. In particular, those supporting the advancement of S&T derive from the principles set by EU's FP7. As mentioned earlier, the Programme—which implements the EU Council's Lisbon Strategy¹⁸ and aims at

¹⁷It is important to explain the way regulation within the EU is structured; Article 282 of the EC Treaty confers upon the EC "the most extensive legal capacity accorded to legal persons" under the national laws of the Member States [to the EU]. The EU does not have such status. For this reason any active law within the EU should be referred to as "EC law" and not as "EU law." Until November 1993, when the EU Treaty came into force, the EU's Official Journal, EUOJ references were to 'EEC' law. Since 1993 the EUOJ has used 'EC'. The EUOJ distinguishes between EC laws and Police/Judicial Cooperation Decisions, CFSP which are Second and Third Pillar (EU) instruments. For example (and in order of legal weight), a Council Regulation is written as 'Council Regulation (EC) 850/2005' in the Official Journal; a Commission Directive is written as 'Commission Directive 2005/37/EC' while a CFSP Decision is written as 'Decision 2001/496/CFSP.' It is imperative to point out that many journalists, politicians, academics and lawyers currently refer to regulatory instruments as 'EU law' when in fact the technically correct term is 'EC law' (Miller and Clark, 2011).

¹⁸The Lisbon Strategy was launched during the meeting of the European Council in Lisbon (March 2000), by the heads of state or government aiming at making the EU the most competitive economy in the world and achieving full employment by 2010. This strategy rests on three pillars: 1) an economic pillar preparing the ground for the transition to a competitive, dynamic, knowledge-based economy. Emphasizing the need to adapt constantly to changes in the information society and to boost research and development; 2) a social pillar designed to modernize the European social model by investing in human resources and combating social exclusion—expecting member states to invest in education and training, and to conduct an active policy for employment, making it easier to move to a knowledge economy—; and 3) an environmental pillar drawing attention to the fact that economic growth must be decoupled from the use of natural resources (EC, 2011b).

turning the continental region into the most dynamic competitive knowledge-based economy in the world— bundles all research-related initiatives within a single program, playing a crucial role as instrument to achieve growth, competitiveness and employment goals. The initiative puts forward an assortment of plans and programs in areas related to modern biotech (biopharmaceuticals, agriculture, the environmental protection, industrial processes, etc.) using a colors nomenclature to differentiate between these.¹⁹ Other rules put forward by the plan are those associated to the operation of multiple structures engaged in the implementation and further policymaking and planning in these areas at the continental, national, and regional levels.

The central regulatory instrument defining guidelines mostly for “green” and “blue” modern biotech is Directive 2009/41/EC on the contained use of genetically modified microorganisms. This legal instrument is oriented towards ensuring the safe handling and disposal of GMOs and parts of these at the earlier research and development stages, especially when these require experimental release or before these can become marketable. More specifically, it does so by setting the guidelines for environmental risk assessment in accordance with the precautionary principle defined within the Cartagena Protocol on Biosafety. These lead to the classification of the contained uses, dividing them into four

¹⁹As in most EU member countries in Spain modern biotech is commonly differentiated using a color terminology developed within the 12th European Congress on Biotechnology (August 2005 Copenhagen, Denmark) organized by the European Federation of Biotechnology. According to this terminology modern biotech can be divided into four general categories (or colors) depending on its focus: white (industrial biotech); red (medical applications); green (food and feed related); and blue (environmental). Policies and regulations promoting the development, use and diffusion of modern biotech contained within the legal framework emanating from the EU Commission and locally enacted can be classified following this color arrangement. Some of these terms have evolved to accommodate more direct associations, even adding new colors to describe less conventional sectors and applications. In particular, blue has been associated to modern biotech associated to the sea and marine species and white (industrial biotech) oftentimes is referred to as gray. Other colors —like brown (biotech related to arid zones); black (bio-terrorism and warfare); gold (bioinformatics, nanobiotech); and grey (classic fermentation and bioprocesses technology)— are among the additions (DaSilva, 2004).

classes, each having individual control levels.²⁰ These rules also establish emergency containment plans and measures for cases when safety becomes an issue or when unintended negative effects arise. This legal framework is complemented by standards provided in Directive 2000/54/EC on the protection of workers from risks related to exposure to biological agents at work.

The legal framework used to ensure adequate levels of protection for human life, health and welfare, as well as for environmental and consumer interest protection is Regulation (EC) 1829/2003 on genetically modified food and feed. The main objective of this law is to reduce risks from the use of GM food and feed, while inducing the least possible distortion to markets for these products. In particular, this regulatory instrument is complemented by both Regulation (EC) 1830/2003, which guarantees traceability and labeling of GMOs or parts of these already in the market as products, and by Directive 2001/18/EC on the deliberate release of GMOs into the environment, which details the principles and sets the rules for the experimental releases and placing in market of GMOs within the EU. These also introduce guidelines on restrictions and vetoing of GMOs harvesting activities in their territory, for food and feed labeling, as well as those regarding the threshold for the presence of GM material that is adventitious or technically unavoidable in products. Together, these three regulatory instruments (along with Directive 2009/41/EC), relying on the European Food Safety Authority, EFSA, define the EC's general authorization procedure for products and activities using GMOs.²¹

²⁰The Community and its Member States signed the Cartagena Protocol on Biosafety to the Convention on Biological Diversity in 2000. The Council Decision 2002/628/EC (5) to conclude the Protocol, on behalf of the Community, was taken on 25 June 2002. It entered into force on 11 September 2003 (EC, 2011c).

²¹On July 13, 2010 the Commission adopted a proposal that provides more freedom to Member States on issues related to GMO crops and their treatment. Although the EC's science-based framework remains unaffected, the proposal provides for non-binding guidelines that better reflect the possibilities already available for Member States when adopting measures to reduce unintended presence of GM varieties within conventional or organic crops. This new package

Although the European part of this policymaking system performs effectively, it does not go without its share of politics. From the perspective of actor S1-P:

Even when the EFSA displays almost complete autonomy in decision-making, always supporting its conclusions and assessment exclusively on scientific evidence and never just on third-party findings or studies, its resolutions are often restrained by external political influence; this pressure induces it to follow an even tighter precautionary principle approach when reviewing modern biotech-derived products and processes, often delaying—or even negating—approval for new products even when its associate experts find these to be completely safe. This behavior stems from the fact that GMOs are still somewhat controversial throughout Europe.

Regarding the protection of fitogenetic material Regulation (EC) 870/2004 establishes a Community programme on the conservation, characterization, collection and utilization of genetic resources used in agriculture. When GMOs are in the form of seeds these are required to obtain authorization by following the principles set by Directive 2001/18/EEC before being included in the Common Seeds Catalogue and marketed within the EU. If these are intended for food, these also require authorization in accordance to Regulation (EC) 1829/2003 on GMO food and feed.²²

includes a commission recommendation on the co-existence of GM crops with conventional and/or organic and provides them flexibility to define lower than the 0.9% unintended GMO presence threshold for labeling (EC, 2003).

²²In addition to the authorization for market placement, genetically modified varieties also need to comply with the requirements of EU legislation on the marketing of seed and plant propagating material, as set out in particular in Council Directive 66/401/EEC (June 14 1966) on the marketing of fodder plant seed, Council Directive 66/402/EEC (June 14 1966) on the marketing of cereal seed, Council Directive 2002/53/EC (June 13 2002) on the common catalogue of varieties of agricultural plant species, Council Directive 2002/54/EC (June 13 2002) on the marketing of beet seed, Council Directive 2002/55/EC (June 13 2002) on the marketing of vegetable seed, Council Directive 2002/56/EC (June 13 2002) on the marketing of seed potatoes, Council Directive 2002/57/EC (June 13 2002) on the marketing of seed of oil and fibre plants, Council Directive 68/193/EEC (April 9 1968) on the marketing of material for the vegetative propagation of the vine, Council Directive 98/56/EC (July 20 1998) on the marketing of fruit plant propagating material of ornamental plants, Council Directive 99/105/EC (December 22 1999) on the marketing of forest reproductive material and Council Directive 2008/90/EC (September 29 2008) on the marketing of fruit plant propagating material and fruit plants intended for fruit

The trans-boundary movement of GMOs is ruled by Regulation (EC) 1946/2003, requiring Community exporters to ensure that all requirements of the Advance Informed Agreement Procedure, as set out in Articles 7 to 10, 12 and 14 of the Cartagena Protocol on Biosafety, are fulfilled.²³

Rules for medical products for human and veterinary use derived from modern biotech are put forward by Regulation (EC) 726/2004, which lays down the Community procedures for the authorization and supervision of medical products for human and veterinary use and establishes the EMA. For various interviewed actors this regulatory instrument has been quite useful as expressed by actor S9-P:

Experience gained during the twenty-something years since the Council adopted its first directives on marketing high-technology medical products —specially those derived from modern biotech— made evident the need for a centralized authorization procedure that is compulsory for these types of products. Thus, justifying the establishment of the EMA. Furthermore, this now centralized evaluation procedure is helping establish higher levels of scientific evaluation for these new products within the EU, especially at a time when the perception and confidence in the evaluation process of patients and medical professionals organization is key for their success and prompt approval. Moreover, EMA can now supervise the operation of the pharmaceutical sector more effectively, as it is becoming the motor behind new gene and cell therapies throughout Europe.

Advanced therapies and other emerging medicines mostly based on modern biotech are monitored through Regulation (EC) 1394/2007 on advanced medic-

production. Among them Directives 2002/53/EC and 2002/55/EC contain provisions, which allow the Member States to prohibit, under certain well-defined conditions, the use of a variety in all or in parts of its territory or to lay down appropriate conditions for the cultivation of a variety (EC, 2011d).

²³Due to the complexity of this requirement, the EC has been engaged in substantial research regarding the possible impacts of ‘asynchronous authorizations’ (which means that a certain GM crop has already been authorized within an exporting country but has yet to be authorized by an importing one). The conclusions of the EC’s latest and more extensive study on this suggest that the presence of non-approved GMOs would become an increasingly important factor that will especially limit future animal feed imports, perhaps leading to further problems regarding the import of non-feed products to the EU (*op.cit.*).

inal therapies. This law is designed to guarantee the free movement of new therapeutic products within the EU and to facilitate their access into local markets, while also fostering the competitiveness of Europe-based biotech companies and guaranteeing higher levels of health protection for patients. The central elements of this regulation focus on: a) creating a centralized marketing authorization procedure; b) forming a new multidisciplinary expert committee within the EMA, to assess advanced therapy products and follow their scientific development; c) setting technical requirements adapted specially for the particular characteristics of these products; and d) creating special incentives for SMEs producing these.²⁴

A series of guidelines affecting the manufacture, characterization and control of drug substances and drug products deriving from modern biotech are also put forward by EMA. Among these are rules for environmental risk assessments for medicinal products containing, or consisting of GMOs; production and quality control procedures for medicinal products derived by recombinant DNA Technology. Also a number of guiding principles on quality of biotechnological products and processes such as those relative to principles for the derivation and characterization of cell substrates used for production of biotechnological/biological products; the analysis of the expression construct in cell lines used for production of rDNA derived protein products; gene therapy product quality aspects in the production of vectors and genetically modified somatic cells; use of transgenic animals in the manufacture of biological medicinal prod-

²⁴Further regulations affecting modern biotech pharmaceutical and medicinal products are: Regulation (EC) 1234/2008 concerning the examination of variations to the terms of marketing authorizations for medicinal products for human use and veterinary medicinal products; Directive 2001/82/EC on the Community code relating to medicinal products for human use; Directive 2001/83/EC on the Community code relating medicinal products for human use; Directive 98/34/EC laying down a procedure for the provision of information in the field of technical standards and regulations; Directive 2004/23/EC setting standards of quality and safety for the donation, procurement, testing, processing, preservation, storage, and distribution of human tissues and cells; Directive 2001/20/EC; among other (Miller and Clark, 2011).

ucts for human use; and production and quality control of cytokine products derived by biotechnological process, among various other.

The protection of intellectual and industrial property associated to modern biotech is specified by Directive 98/44/EC on the legal protection of biotechnological inventions. The instrument, more than creating a separate body of law for these types of inventions, puts forward a series of revisions to the existing IPR guidelines that allow treating modern biotech-derived inventions like any other industrial innovation. It also serves as reference for the harmonization of rules on the legal protection of biotechnological inventions among member states, especially those areas regarding patentability of living organisms and basic biological processes as well as on issues regarding discrepancies between discovery and invention, and on the principles behind patentability criteria.

As mentioned earlier, these communitarian regulations establish the general rules for modern biotech in all EU members, setting the framework from which all local regulatory instruments are hanged from. Local regulations are then designed (or revamped) to detail their implementation at the state and regional levels.

2.2.7 Contrasts and Findings

General Observations

There are palpable differences between the systems of innovation and technology operating in these two countries. The most obvious stem from their regional economic and geo-political organization; while Mexico benefits from being neighbor to the largest global economy and from the economic opportunities derived from NAFTA, by no means has it gained from this as much as Spain has from being a member state to the EU. As such, Spain has had access to in-

stitutional resources that—to this date—continue assisting in the consolidation of its modern biotech sector. It also has benefited from the adoption of sophisticated communitarian regulations that have as well helped setting the proper environments for this sector to bloom. Furthermore, planning at a communitarian level has promoted the establishment of a general institutional and regulatory structure throughout Europe that operates as a single system, allowing multiple other resources (i.e. information and human capital) to reach all members and regions and for these to collectively benefit from them, something that has also worked in favor of the Spanish modern biotech sector.

In Mexico, on the other hand, the flow of resources to sectors associated to modern biotech has been limited and the existing regulatory and political frameworks promoting these have yet to produce alluring enough incentives for private investors. The absence of a general programmatic mechanism that encourages the formation of technological systems (actor-networks) and the channels that could help taking advantage of its closeness to the US and Canada seem to have also assisted in delaying not only the rise of a local modern biotech sector, but the advancement of R&D in general. Few—if at all—are the international institutional resources assisting in the expansion of the local modern biotech sector, and no initiatives to develop any within the NAFTA framework appear being in sight.

Although Mexico has membership to various international agreements and organizations that help define global guidelines on issues related to modern biotech (UN, WTO, OAS, etc.), the absence of a factual reference point to look up to when defining these at the local levels has also added to the sector's structural drought. At times, local regulators have to choose between following the approach displayed by the US for these or the more precautionary one proposed

by the EU when drafting these rules.

It will require much political maneuvering to encourage a revamping of the current MBTS in Mexico in order to establish novel and functional rules that let it perform in ways similar to the systems-oriented approach observed in Spain. As witnessed during the enactment of the Biosafety Law, segments of the local policymaking system do not seem too elated by the notion of setting (or reducing) rules that encourage a more active role of the private sector in these areas, especially when these are closely associated to areas like the access to genetic resources and IPRs on these. Yet, rules for these areas appear to be long overdue—as corroborated by the multiple views captured in the previous sections. Furthermore, additional frameworks might also require substantial reform (investment and funding, education, fiscal and other public incentives, etc.) to guarantee the local formation of environments analogous to those that helped fostering entrepreneurship in modern biotech in Spain.

As part of a larger system, Spain has developed more stylized (and sometimes too intricate) networks than those currently operating in Mexico. In Spain, the composite associations between individual and/or institutionalized actors appear to both facilitate the information and resource flows within these network-systems and to induce the development of multiple informal guidelines that—generally—become the basis for future formal rules. This is basically the cycle that has allowed the sector to move forward. Examples of these are: the principles behind the interaction between patients and drug developers; guidelines for data use and access among different research teams within a single cluster; and those developing between same-project public and private investors. Even before reaching considerable levels of formality these tacit agreements help defining the systems-network's boundaries and pinpointing new

actors and institutions.

Although Spain has successfully managed to shape for modern biotech an environment that guarantees collaboration and coordination between sectors, promotes research, and generates high-quality products and services, one of the most serious challenges it still faces is finding ways to further encourage private investment in basic research activities. As mentioned in the opening section of this chapter, this lack of interest mostly appears to be due to the difficulties of determining beforehand the possible findings and applications that may result from such research endeavors. As a consequence projects not carried within the in-house' labs and research centers these investors control generally struggle harder for private resources.

Aware of this shortage, there has been a rise within the Spanish network of systems of a particular type of bridging figure; a type of connector or "match-maker" serving as link between venture capital investors and promising projects. Some of these actors also help projects become more attractive for investors by sharing cost with them or by facilitating the access of these to the enormous array of R&D funding schemes for basic research emanating from the EU and other national frameworks. Although this novel approach, thus far, has displayed modest benefits for basic research projects and it is often cited as insufficient to completely bridge the gap between basic and applied research, its principles have become the source for numerous other initiatives (i.e. bioregions, non-for-profit organizations, scientific clusters, etc.) aiming at the same bridging objectives. These have taken more active roles finding novel ways to encourage the formation of links between actors, groups of these, institutions, and sectors (i.e. basic and applied research, private investors, the public sector, particular interest groups, international organizations, etc.), creating further

network-inducing mechanisms and adding to the set of informal guidelines that define and expand the overall system. Furthermore, IPRs regulation in Spain is ahead to that of Mexico by establishing clear guidelines for benefits distribution among private and public actors derived from inventions produced within public research institutions or within the scope of public-private agreements.

Particular Findings

A closer analysis of both nations' approach towards the promotion of R&D and modern biotech shows that the richer network of systems operating in Spain has encouraged the rise of key actors and associations that help further promote the advancement of the sector. It also provides more evidence to suggest that Spain's particular regional and socio-political conditions may have had a higher hand in the development of the environments necessary for these systems to rise and flourish than previously estimated. This has also lead to consider that a series of further structural and institutional reforms beyond those exclusively targeting R&D and modern biotech promotion will be necessary in Mexico before the development of many of the essential elements that could help shape a comparable system to that of Spain takes place. Further, it suggests that a number of factors that allowed the development and expansion of the sector in Spain may not yet be available in Mexico, and that a simple adaptation of the resulting institutions could not be the finest path of action.

To finalize this section and chapter the most relevant elements composing each system are presented in table 2.3. The next chapter I will formalize this analysis through the use of systems dynamics modeling techniques to further elaborate on this comparison.

Table 2.4: Key Elements in Spain and Mexico's MBTS

	MEXICO	SPAIN
Institutional		
Central Regulatory Authority (GMOs)	3 Secretariats (Health; Environment; Agriculture)	CIOGM (s) ²⁵
Advisory, Coordination, and Promotion (GMOs)	CIBIOGEM; CONACyT	CIOGM(s); NBC(s); Regional Control Office(Mad.); Regional Biosafety Commission(Mad.)
S&T and Biotech Promotion (Public)	CONACyT; CIBIOGEM; RENIECyT	ERC(EU); MICINN(s); CSIC(s); CDTI(s); RBR(s); BioCat(Cat.); <i>Madrid Biocluster</i> (Mad.)
S&T and Biotech Promotion (Non-public)	AMC; SBMM; <i>AgroBio México</i>	EFB (EU), <i>ASEBIO</i> (s); <i>Catalonia Bio</i> (Cat.); <i>BIOMADRID</i> (Mad.)
Pharmaceuticals and Medicines (Including biotech)	COFEPRIS	EMEA(EU); MSC(s) AGEMED(s);
Food Safety (Including biotech)	SENASICA	EFSA (EU); MMA(s); CFSA (Cat.); MSS (Mad.)
	Continued ...	

²⁵(s) Spanish regulation; (EU) and (EC) stand for European Commission Regulation.

Table 2.4: (continued)

	MEXICO	SPAIN
...		
Environmental Protection (Including biotech)	PROFEPA; INE; CONABIO	AEMA (EU); MMA (s)
Industrial Products and Services (Including biotech)	NA	EFESA (EU); MSC (s); MMA (s)
Basic Research (Including biotech)	UNAM-iBT; IPN-CINVESTAV; CBG; INIFAP; IMP; U. <i>Chapingo</i> ; Post-Graduate College; ITESM; Other	CSIC(s); CDTI(s); INIA(s); CNB(s); IDAB(s); IBBTEC(s); CRAG(s); IREC(s); Other
Genomics	INMEGEN; CNBio	EMA (EU); MICINN(s); CRG(Cat.)
IPRs (Including biotech)	IMPI	EPO(EU); OEPM(s)
Public Funding (Including biotech)	CONACyT; CIBIOGEM; Ministries	EC(EU); MICINN(s); <i>Genoma España</i> (s); BioCat(Cat.); <i>BIOMADRID</i> (Mad.)
Private Funding (Including biotech)	NA	Multiple; (EU, National, and CCAA)
	Continued . . .	

Table 2.4: (continued)

	MEXICO	SPAIN
...		
Regulatory		
S&T Regulation	<i>LCyT; Reglamento LCyT; Ley Organica del CONACyT</i>	<i>Ley 14/2011(s)</i>
S&T Promotion	PND; STSP	PF7(EU); PNI&D+i(s) <i>IDEAS(EU)</i> ;
Biosafety Regulation	LBOGM; <i>Reglamento LBOGM</i>	Directives 2009/41/EC and 2000/54/EC; <i>Ley 9/2003(s); Real Decreto 178/2004(s)</i>
Human Health biotech)	(Including General Health Law and its <i>Reglamentos</i> for: GH, Products and Production Processes, Sanitary Protection for Product and Services, Health Inputs, Publicity, Research on Human Health	Regulation (EC) 726/2004; <i>Ley 29/2006(s); Decretos Reales 1345/2007(s) and 1201/2005(s)</i>
	Continued ...	

Table 2.4: (continued)

	MEXICO	SPAIN
...		
Plant Protection (Including biotech)	Plant Health Law; Seed Production, Certification, and Trade Law; Organic Products Law; Sustainable Rural Development Law	Directive 2001/18/EC; Regulations (EC) 1829/2003 and (EC) 870/2004; <i>Leyes</i> 30/2006(s) and 3/2000(s); <i>Decretos Reales</i> 1891/2008(s); 289/2003(s); and 929/1995(s); <i>Reglamento</i> for the registry of commercial vegetable varieties(s); and <i>Orden</i> ARM/405/2009(s)
Food and Feed Safety (Including biotech)	General Health Law and <i>Reglamentos</i> for: GHF; Products and Production Processes	Regulations (EC) 1829/2003 and (EC) 1830/2003; <i>Ley</i> 30/2006 (s)
Animal Health (Including biotech)	Animal Health Law and <i>Reglamento</i>	Regulation (EC) 726/2004; <i>Ley</i> 8/2003(s); <i>Decretos Reales</i> 488/2010(s); 1201/2005(s); 1246/2008 (s); and 109/1995 (s)
	Continued ...	

Table 2.4: (continued)

	MEXICO	SPAIN
...		
IPR Regulation (Including biotech)	Industrial Property Law	Directive 98/44/EC; <i>Leyes</i> 11/1986 (s); and 10/2002(s); ²⁶ <i>Real Decreto</i> 55/2002
Infractions	Mexican Penal Code; Individual regulations (GMOs)	<i>Ley Orgánica</i> 10/1995 (Penal Code); Individual regulations (GMOs)
Other		
Continental or Regional R&D framework	NA	PF7; ERA; ERIC
Regional Industrial and R&D Clusters (New Life Sciences)	<i>Biocluster de Occidente</i>	RBR(s); <i>Madrid Biocluster</i> (Mad.); PRBB(Cat.); PCB(Cat.)
Top Industry Modern Biotech Associations	SBMM; <i>AgroBio México</i>	EFB(EU); <i>EUROPABIO</i> (EU); <i>ASEBIO</i> (s); <i>Catalonia Bio</i> (Cat.); <i>BIOMADRID</i> (Mad.)
	Continued ...	

²⁶This regulation is exclusively for modern biotech products.

Table 2.4: (continued)

	MEXICO	SPAIN
...		
Institutionalized Public Participation	NA	At the EU, National, and Autonomous Community levels through various channels (Ministries and Agencies)
Linkage (Knowledge and Tech Transfer)	Subsidies; Tax Incentives; Single Cluster	OTRIS(s); CTs(s); CAITs(s); S&T Parks and Clusters; Technology Centers; Technology Platforms; Tax Incentives; Subsidies
Business and Economics	NA	<i>Ley de Economía Sustentable(s)</i> (bill)
International Agreements	CBD; Cartagena Protocol; <i>Codex Alimentarius</i> ; TRIPS	CBD; Cartagena Protocol; <i>Codex Alimentarius</i> ; TRIPS
	End	

CHAPTER 3

DYNAMICS OF TWO MODERN BIOTECH SYSTEMS OF INNOVATION

3.1 Modeling Spain and Mexico's Modern Biotech Systems

As suggested by the findings presented in the previous chapter, the modern bio-technological systems of innovation operating in Spain and Mexico display both differences and similarities; while some of these seem to be deriving from regional integration and global economic flows, others appear stemming from political principles and methods well rooted within the actors and institutions composing them. A closer review of these results as well as the analysis of multiple studies on the economics of scientific development and on the structure of systems of innovation allowed sketching a general bio-technological systems of innovation model (general model from hereon) which displays components commonly found in both systems.

It is important to emphasize that the structure of this “generic” model was mostly developed borrowing concepts (assumptions, variables, parameters, logical relationships, etc.) from neoclassical, endogenous growth theory, and system dynamics models as well as from principles found within the regional systems of innovation literature. When findings from the interview analysis process help further explain this general model's structure or behavior these are modeled and introduced into particular sections of it. In cases when findings explain traits specific to either system, these are modeled and introduced into later model versions used to assess the effects of such structural and regulatory variations. In other words, particular traits are introduced to the general model when it is set to represent either of the systems under scrutiny. Albeit these considerations, the overall design of this general model ultimately rested on my

personal conjectures regarding the layout of a modern biotechnological system of innovation.

This general model, developed using specialized system dynamics modeling software, not only provides a broader view of the key institutions, policies, actors, and connectors composing both systems but also helps to explain the interaction and dynamics of these when engaged in knowledge and innovation processes. Furthermore, its design permits switching “on” or “off” some of its parts in order for it to resemble and perform more similarly to either of the biotech systems analyzed. Additionally, a number of variables in each ‘adapted’ version can be calibrated using data from each country to set the initial conditions that allow it to behave more consistently with the system it is set to represent. This comparative exercise allows a straightforward contrast between these systems’ structural composition and performance over time. Moreover, when checking for sensitivity to changes in aspects associated to regulation (IPRs, biosafety, health safety levels, etc.), policy planning (government funding to R&D, taxes, international funding, etc.), or innovation management (technology transfer, clustering, venture capital investment, etc.) sufficient information can be obtained to define a series of policy recommendations on how to further advance the performance of Mexico’s MBTS as represented by the model. Overall, based on the assumptions and principles defining the general model, this exercise offers additional elements to help support the hypothesis that Spain’s MBTS performs more efficiently than that of Mexico. Lastly, the findings also help suggest that the Latin American country could learn from the European’s positive experience when designing future policies to promote the creation of markets for products and services derived from the use of modern biotech. The following sections present a general overview of the methodology followed to

define, calibrate, and validate the results obtained as well as a highly detailed account of the design of the models considered.

3.1.1 Discussion of Methods I: Overview

This segment provides a brief step-by-step outline of the methodology followed to design and assess the computer-based formal systems framework for conducting thought experiments about science and technology policies that rests at the heart of this project. It serves as an overview for the more detailed description of the methods for this section presented later in the chapter. This first introduction, more than delving into the design of the various model versions and its parts, summarizes the series of steps followed to calibrate and validate each part as well as those to produce and validate their results. It also describes how comparisons between model versions was performed and how some of these models were determined to perform better than others and, thus, how the conclusions for the various experiments performed were reached. It is important to say that the overall methodology described here is based on that originally proposed by Milling and Maier (1993); Maier (1998); Milling and Maier (1996, 2001); and Milling (2001, 1996) in which modeled systems link cognitive processes to computer routines and allow insights into the true behavior of particular systems of innovation. Yet, the use of the approach here presented allows concentrating more on the performance of the systems as these change over time as well as on how specific structural variations alter their behavior. Essentially, this approach can be considered as one that combines theory-based investigation and the practical research of laboratory experiments and constitutes, as Milling suggests, a third pillar for rational decision making in R&D policy.

Defining a General Model

The first step in this process was to produce a “general” MBTS model that borrowed elements from various existing models currently used to explore the economics of innovation (Arrow, 1959; Caballero and Jaffe, 1993; Lucas, 1993; Milling and Maier, 2001; Romer, 1990; Segerstrom, 2007; Shone, 2001); captured behavioral assumptions from multiple economics and systems of innovation theories (Aghion et al., 1998, 2009; Balzat, 2006; Kamien and Schwartz, 1982; Freeman and Polasky, 1992; Lundvall, 1985, 1988, 1992, 1998; Lundvall et al., 2009; Romer, 1994; Solow, 2000); and was able to display the behavior of a system of innovation using a system dynamics approach (Forrester, 1961; Legasto et al., 1980). For this design it was also necessary to consider the more refined understanding of the interactions happening within the areas composing these systems provided by the various key actors interviewed in both countries.¹ The resulting general model comprises five inter-linked modules: 1) Research; 2) Development; 3) Innovation Management; 4) Resource Management; and 5) R&D Policy.²

This comprehensive model introduces factors associated to the behavior of the economic agents and the institutions behind innovation processes and explores their role in what some authors define as knowledge-based growth (Freeman and Polasky, 1992; Loasby, 1999). It also examines how the dynamics between these actor-networks and institutions and changes to the system’s overall structure affect the performance of its individual parts (Malerba, 2005).

¹In upcoming sections it is clearly signaled where the views and opinions of these experts were considered to define the structure and behavior of the multiple model versions.

²Each of the modules are described from inception to performance in the following sections.

Initial Experiment: Treatment Ranking

The initial experiment using this model allows comparison of the effects that change to a number of “control factors” have on its performance as measured by the behavior of selected response variables.³ These factors are five structural elements that can be either switched “on” or “off” and the level of two parametrical variables that can be either reduced, kept constant, or increased within the modeled system.⁴ Individual changes to these controlled factors or combination of these are defined as ‘treatments.’⁵ In order to measure the true effects that these treatments have on the general model’s variables, each is applied while keeping all of its initial conditions constant.⁶ Therefore, this process

³The selected response variables are: 1) new research (new knowledge); 2) research potential; 3) new development (new innovations); 4) development potential; 5) to market (new marketable products); 6) patented knowledge; 7) open access knowledge; 8) research infrastructure capacity; 9) development infrastructure capacity; 10) government income; 11) venture capital to research; 12) venture capital to development; 13) level of existing genetic resources; 14) biosafety level; and 15) health safety inspection level. Although the model displays other response variables, these were not assessed in this process. Among these are: resources to research coming from tech transfer to research; resources to research coming from tech transfer to development; R&Ds savings and expenditure level; and labor hand going to research and development.

⁴These structural elements that can be switched “on” or “off” capture the presence of venture capital investment (including international venture capital); the ability of the system to allow research and/or development clustering; labor mobility between research and development; and a “royalty-sharing” rule that defines how the results of publicly funded research is allocated. The two parametric factors, on the other hand, affect the behavior of IPRs by extending, reducing, or keeping constant the length (25 years) and the breadth (set at 50%) of IPR protection. A further structural element, defined as “match-making” is intrinsic to both, the venture capital variable and the clustering elements in the model; when venture capital is present in the model, these two effects encourage investment in either sector (R or D) when either displays both low financial resources and a high payback probability (as measured by its debt/income ratio), or suggest the existence of a “common objective” that encourages intra-sector collaboration at any given time. A last switch within the model represents the presence of a fixed amount of funds coming from the government for R&D. However, due to the fact that both Spain and Mexico have such a fixed amount of resources per period this switch remains always “on” in every model’s version and run.

⁵It is important to point out that when a particular treatment is applied to the general model, the resulting model is considered to have become a different or “new” model. Therefore, the terms ‘treatment,’ ‘model,’ and —later in the chapter— ‘policy’ all refer to the same concept in this chapter and throughout this study.

⁶The initial conditions considered in this general model are: Yearly interest rate at 3%; price of knowledge units, 10; labor hand levels at 10,000 (with a research-to-development ratio of 3:1); level of existing research infrastructure at 10 million (requiring 1,000 units per research worker); level of existing infrastructure for development at 2 million (requiring 2,000 units per develop-

allows ranking of the effectiveness of each treatment as measured by variable response over time.⁷ Due to the substantial number of treatments that can be generated through combinations of controlled factors, five with two levels and two with three for a total of 288 ($2 \times 2 \times 2 \times 2 \times 2 \times 3 \times 3 = 288$), a subset of 34 treatments is used to study the relationship between these and the response variables' behavior. The random component at the heart of the general model requires it to be run 100 times under each of the treatments to produce substantial enough data to capture the behavior of each assessed variable. For every response variable the arithmetic mean of 100 observations per simulation period (50 periods in total representing 25 semi-annual measurements) is obtained and used to define a single general observation per treatment per period. Such data serve to run time series regressions used to obtain the trend lines that reflect the effects that each treatment has on each response variable over time. The equations for these trend lines offer enough information to make comparisons between treatments (models, policies) and between the behavior of each of the response variables in each model. In other words, these allow measurement of the effectiveness of each of the different model versions and provide more elements to help conclude if—in fact—Spain's MBTS as modeled is more efficient

ment worker); government resources, 10 million, with fixed funds to R&D at 0; net financial resources to research, 5 million; net financial resources to development, 5 million; venture capital funds 10 million; international venture capital available at 10 million (with 100,000 entering the fund each cycle and 1% of the total fund going to investment, when available); savings and spending both at 0; patents at 0; public knowledge at 100; IPR length at 25 years and breadth at 50%; the levels of natural resources and genetic resources at 10 million; biosafety at 10 million, with an inspection level of 100,000; and health safety all at 10 million, with an inspection level of 200,000; and new research and new development set both to a level of 1 to avoid divisions by zero. These conditions were estimated to guarantee an overall stable performance of the model.

⁷As suggested, when a treatment is applied to the general model the resulting structural and parametrical composition is considered itself to be a new model. Thus, two particular treatments allow to define the general model as either one representing the system operating in Spain (all structural factors on and parametrical factors constant) or as one representing the system operating in Mexico (all structural factors off and parametrical factors constant).

than that modeled as operating in Mexico.⁸

Using the equation parameters obtained through time series analysis for each variable, the results are reviewed at 10, 20, and 50 periods (5, 10, and 25 years, respectively) and contrasted with those obtained for each at 2 periods (first year). This allows one to understand how the response variables behave over time (short, mid, long term) when the model is under each of the treatments. It further allows one to determine the degree of response that each treatment induces on the variables in each term as well as the percentage change that each of these responses have compared to their initial level at year 1. These results—defined as consistency and performance, respectively—are then ranked at each time period with respect to the results produced by the neutral treatment or model for Mexico (all structural factors off and parametrical factors constant or “All Off”). Finally, based on these performance and consistency levels, each treatment’s overall effectiveness is ranked among “best,” “moderate,” or “unsatisfactory” treatments. This initial experiment allows sorting out the best response-inducing treatments from those with less positive effects on the selected variables. It also allows determination of where the treatments for Spain and Mexico rank among this list. Also, by not introducing initial conditions from either Spain or Mexico into the general model the process removes any possible effects on the variables’ behavior that could be due to the induction of these.

Due to the large quantity of information produced by this process (15 variables x 34 treatments = 510 total results), the results reported for each treatment using the described methodology are exclusively those for the pivotal variable “New Development.” This variable displays the number of new marketable

⁸The next section delves into the regression processes followed and the types of equations used to assess each variable.

products or services (new markets) in modern biotech that each modeled system produces per term.

Second Experiment: Assessing Each Particular System

While providing a first approach to help conclude if the modeled system for Spain in fact outperforms that for Mexico, the initial experiment also helps to determine the effects that these two treatments have on the behavior of the variables before particular conditions from each country are introduced. The second experiment consists precisely of introducing as much data from each country as possible into each version of the model before assessing and contrasting their results. New conditions are introduced by setting the initial rates and levels for particular flows and stocks at amounts that reflect those displayed by the real elements modeled within each of the MBTS analyzed.⁹

Although the absence of formal data and the fact that data collection processes in the realm of modern biotech are still at primitive stages in both countries, various initial conditions can be gathered or defined and introduced in each model. For the case of Spain the initial conditions were gathered from three main sources: *Relevance of Biotechnology in Spain 2009* (Genóma España, 2009); *OECD Biotechnology Statistics 2009* (van Beuzekom and Arundel, 2009); and *Informe Anual 2009* (ASEBIO, 2010).¹⁰ For Mexico's model these conditions

⁹Though more initial conditions are available and can be introduced into the model representing Spain's MBTS, the number of these has to concur with that of variables available for the case when the general model describes Mexico's system; a restriction that derives from the limited available data for the sector in that country. The agreement in the number of adjusted initial conditions between model versions is also considered essential to provide more validity to the response comparison procedure. Furthermore, the level at which some of these parameters are set also allows for each transformed versions to keep some of its original initial conditions and still function adequately.

¹⁰The initial conditions introduced to the model for Spain are: Interest rate at 3%; tax rate at 35%; price of knowledge units, 100 (one "knowledge currency" token equals 100 "knowledge units"); labor hand levels at 18,000, with a level of 1,000 entering the sector per cycle (with a research-to-development ratio of 3:1); level of existing research infrastructure at 400 million

were either obtained or calculated using data produced by the National Institute of Statistics and Geography, INEGI and by the Mexican Academy of Sciences, AMC.¹¹

(requiring 10,000 units per research worker per cycle); level of existing infrastructure for development at 180 million (requiring 2,000 units per development worker per cycle); government endowment to R&D at 507 million; net financial resources to research and net financial resources to development, 0; venture capital funds 120 million; international venture capital available at 100 million (with 100,000 entering the fund each cycle and 1% of the total fund going to investment, when the model suggests availability); savings and spendings both at 0; patents at 200; public knowledge at 1,000; IPR length at 25 years and breadth at 50%; the levels of natural resources and genetic resources at 10 million; biosafety at 10 million, with an inspection level of 100,000; and health safety all at 10 million, with an inspection level of 200,000; and new research and new development set both to a level of 1 to avoid divisions by zero.

¹¹These initial conditions are: Interest rate at 3%; tax rate at 35%; price per knowledge unit 100; sector's labor hand at 14,500, with a level of 1,000 entering the sector per cycle and a research-to-development ratio of 1:5; level of existing research infrastructure at 90 million (with 5,000 units per research worker every cycle); level of existing infrastructure for development at 32 million (requiring 2,000 units per development worker per cycle); government endowment to R&D at 430 million; net financial resources to research and net financial resources to development, 0; venture capital funds, 0; savings and spendings, 0; patents at 186; public knowledge at 1,000; IPR length at 25 years and breadth at 50%; the levels of natural resources and genetic resources at 10 million; biosafety at 10 million, with an inspection level of 100,000; and health safety all at 10 million, with an inspection level of 200,000 (equal to Spain to suggest an "international standard"); and new research and new development set both to a level of 1 to avoid divisions by zero. Mexico's human resources in S&T are calculated using two tables developed by INEGI: *Recursos humanos: Población que completó exitosamente el nivel de educación ISCED 5 o superior y está ocupada en actividades de ciencia y tecnología, por nivel de educación y campo de la ciencia según ocupación, 2008* and *Recursos humanos: Miembros del sistema nacional de investigadores según área de conocimiento, 1991-2010* (INEGI, 2008, 2011). More specifically, by adding the totals for *ciencias naturales y exactas* (200,681), *ingeniería y tecnología* (629,833), *ciencias de la salud* (502,389), and *ciencias agropecuarias* (111,972) presented in the first table, a total of 1,444,875 is obtained as Mexico's available human resources in S&T. Determining that biotech accounts for about 1% of all S&T human resources, the figure for the sector comes to be somewhere near 14,500. Then, by adding the totals for *biotecnología y ciencias agropecuarias* (1,711) plus a fraction (10%) of *Biología y Química* (244) and *Medicina y Ciencias de la Salud* (144), found in the second table's data, an approximation to the total number of researchers in biotech or areas related can be calculated for the year 2008. This sum allows estimating a total of 2,100 as the number of researchers in biotech and 12,400 as those engaged in development activities in this area. According to a study on the state of biotech in Mexico developed in 2010 by the AMC, there are nearly 45 major research centers in the country (including professional associations, like the SBMM). Determining that each can allocate 2 million in resources for human capital, the total infrastructure for human capital in basic research in Mexico is estimated at 90 million (a capacity of 18,000). For development, the same source suggests that approximately 375 industries are engaged in producing these technologies locally. Determining for these a budget for human capital of 85,000 for each, total infrastructure for human capital in development can then be estimated at 32 million (a capacity of 16,000). The difference in costs in human capital personnel (5,000 for those in research and 2,000 for those in development) is introduced in the model to capture the higher sophistication (facilities, labs, and other research instruments) that research infrastructure requires to accommodate its human capital. Development work force, on the other hand, requires less resources as it focuses more on the sector's managerial and production activities. Therefore,

Analogous to the first experiment, to produce substantial enough data to determine the behavior of the assessed variables under each model, each is run 100 times. Once again, for every response variable the arithmetic mean of 100 observations per simulation period is obtained and used to define a single general observation per treatment per period. Such data are used to run time series regressions to generate the trend lines that capture the behavior of each variable over time. The equations for these lines are then used to make comparisons between the behavior of each response variable at different time periods within each model and later to make these comparisons between the results obtained for each model. Within models, the results obtained for each variable at 2 periods (1 year) are contrasted with those produced for each at 10, 20, and 50 periods (5, 10, and 25 years, respectively). This helps to obtain more information about the effects that these modeled systems have on the selected variables. Between models, the results for every variable at each of these cycles (2, 10, 20 and 50 periods) are contrasted to determine which treatment induces a more significant variable response in the short, mid, and long terms. This allows estimation of what the areas and terms are in which each model performs more efficiently.

To validate the information produced by these models the variable *Patentable Knowledge*—for which data are relatively available and which engulfs the behavior of multiple of the reviewed variables—is used as proxy. With the use of statistical analysis software the distribution that best fits the forecasted data is determined. Then, the average number of patents produced between 2000 and 2008 for each country is used as validation parameter; if this average falls within the projected data's distribution range (percentiles), then it can be inferred that the data forecasted by both models behave similarly to the official data and,

such resources are mostly aimed at salaries and other types of compensation. Finally, the same AMC study estimates the number of patents associated to modern biotech in Mexico at around 186 (AMC, 2010).

thus, that both models reflect the performance of these systems.

Third Experiment: Testing Best Systems

To provide more insights on what policies Mexico can pursue to optimize the effectiveness of its MBTS, this third experiment assesses the performance of the model for Mexico while under the treatment that ranked as “best.” In other words, it tests the variables’ response using a model with all structural elements “on,” both parametric factors reduced,¹² and the initial conditions for Mexico in place. This process contrasts these results with both, those gathered using the original model for Mexico and those obtained from the model for Spain. Therefore, it determines which of these models can be considered a better ‘variable response-inducing policy.’

Again, the process to determine the response of the selected variables relies on running the model 100 times, obtaining for every response variable the arithmetic mean of 100 observations per simulation period, and using it to define a single general observation per treatment per period. These data help to produce the time series regressions necessary to generate the trend lines that capture the behavior of each variable over time. The equations for these lines also serve to make the necessary comparisons between the behavior of each response variable at different time periods within the “best” model and then to make comparisons between these results and those previously obtained using the original model for Mexico and that for Spain. Within this enhanced model, the results obtained for each variable at 2 periods (1 year) are contrasted with those produced for each variable at 10, 20, and 50 periods (5, 10, and 25 years, respectively). This estimates the behavior of the variables over time under this

¹²In this case the length of intellectual property protection (IPRL) is reduced from 25 to 15 years, while the breadth of their protection (IPRB) is reduced from 0.50 to 0.25.

policy. Between these three models, the results for every variable at each term (2, 10, 20 and 50 periods) are contrasted to determine which induces a more significant variable response in the short, mid, and long terms.

This last experiment rounds-up a series of tests that allow it to conclude if Mexico's current MBTS is underperforming as compared to that of Spain and to help define concrete policy recommendations on how to make it operate more efficiently and expand modern biotechnology locally. Overall, these experiments also serve to define a number of theoretical considerations to help expand the theory and methods behind these experiments and to open the door for various research leads in areas related to modern biotechnology and innovation in Mexico.

3.1.2 Discussion of Methods II: General Model's Structure and Key Components

The intricate networks and multiple dimensions in which the elements composing these technological systems simultaneously operate made the design of a general model quite a complex task. For instance, these systems can be modeled to represent the dynamics of the private industry as it engages in the development of new products (markets for innovation) and deals with the entry of new competitors, giving public policy a secondary role. Conversely, these systems can also be modeled to describe the dynamics of multiple sectors (industry, government, research, etc.) operating within a public policy framework in which producing and transforming the results of research becomes a collective effort. These sectors would then be aiming at maximizing the potential of R&D as a single system. This latter approach is, in essence, the one here

presented. In other words, the perspective from which the general model is sketched is that of the central planner who engages in the design of an optimal policy framework; focusing mostly on those elements and interactions associated to the promotion of biotech and science that are directly influenced by or considered within public policy decisions and aiming towards maximizing social benefit through the expansion of R&D potential and the creation of markets. Yet, aspects of private endeavor and industrial organization —like investment or technology transfer levels, licensing terms, or labor mobility— are also given adequate weight within the model.

It is important to point out that, contrary to most economic growth theory models, the focus of this model is not to determine and maximize a production function for R&D with specific output elasticities between its inputs. More specifically, the model centers on assessing the potential of the sector over time from an evolutionary perspective, taking into account the interactions between the stochastic nature of discovery and the continuous advancements in R&D methods and available resources. This approach is consistent with that of Maier (1998), Milling (2001, 1996), and Milling and Maier (1993, 1996, 2001), whose premise suggests that any attempt to characterize a production function for R&D the same way as those for material goods are could be quite an impractical and unproductive task. In their own words:

[R]esearch and development deals largely with intangible and at least partly stochastic processes. The uncertain outcome of industrial R&D is commonly observed. In literature many attempts are described to define a production function for research and development similar to that of material goods. These R&D production functions use as input resources allocated like budget, number of people assigned or laboratory equipment available. As output for example the number of innovations or patents used. These approaches to model R&D processes fail for several reasons; First, R&D is highly stochastic, and the input-output relation mapping the R&D production function must also be stochastic. Second, the output is extremely

heterogeneous, which leads to measurement problems (see Schröder (1973) for a discussion of production functions for R&D). Additionally, these models are black box approaches; they are not successful in describing how the various factors influencing the outcome of this stage operate together and are not suitable to generate insights in the development of technological innovations over time. [A] different approach is suggested. Since the development of knowledge can be seen as an evolutionary process, an analogy to biological evolution theory [can be used to define] how new concepts develop by the variation and mutation of existing and known solutions. [R]esults are evaluated on the basis of their viability. If they seem to be superior to previous combinations, they are selected for further development, and hence for future evolution; otherwise they are discarded. (Milling and Maier, 2001)

The use of such an approach within the general model here presented allows concentrating more on the overall performance of the sector as it changes over time as well as on how specific variations to its structure alter its behavior. The following section describes the elements, connectors and dynamics of each of the modules composing the general model as well as a more detailed account of the adapted biological evolutionary process of R&D found at its core.

A Detailed Description of the General Model

As mentioned in the methods introduction the general model is divided into five sub-systems or modules: 1) Research; 2) Development; 3) Innovation Management; 4) Resource Management; and 5) R&D Policy (see figure 3.1). These modules are linked together through a network of connectors, each displaying a different polarity depending on the association these establish. The interconnections between modules create sub-network that either balance or reinforce the relationship between these. Particularly, Research, Resource Management, and Development form a reinforcing loop, while —at the same time— both Research and Development establish a balancing one with Innovation Management. On

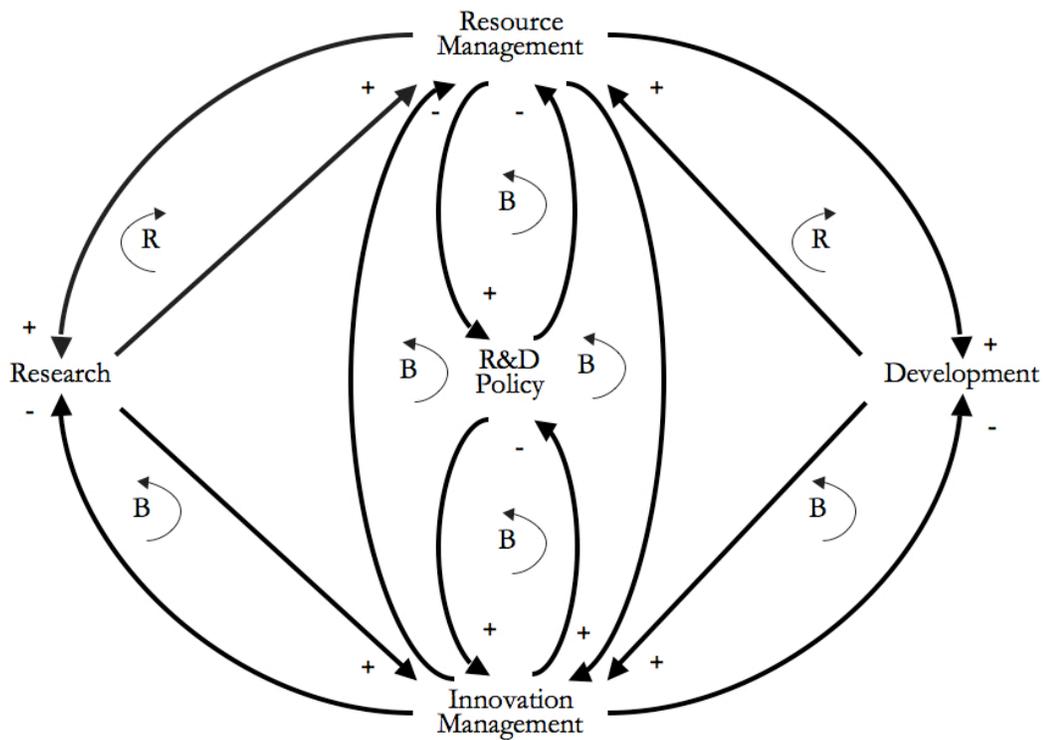


Figure 3.1: Map Layer: Modern Biotech Systems Model

the one hand, this is due to the use of multiple resources in both knowledge creation (research) and innovation production (development) and to the feedback that these provide as they expand the resource pool for future activities in both sectors.

On the other hand, innovation management assists in setting the levels at which these resources are depleted and looped-back into the resource pools. Simultaneously, Resource Management, Innovation Management, and R&D Policy create a balancing loop between them providing the model with stability as these engage in a tacit negotiation to establish the optimal levels of depletion and the rules for the access to basic inputs in order to maintain a sustainable level of these for R&D activities.

Research

This module focuses on the behavior of two central stocks: one describing the system's research potential and another measuring the level of new knowledge created and transferred over time. These two stocks are defined by the following equations:

$$RP_t = \int_0^t (InputR_t - OutputR_t) dt + RP_{t-1} \quad (3.1)$$

where RP_t is the overall system's research potential level as measured by a stock of inputs; $InputR_t$ is the sum of all inputs used in knowledge production at time dt ; $OutputR_t$ represents the total depletion of these inputs at time dt ; ¹³ and RP_{t-1} is the initial level of research capacity.

The variables in this first equation are:

$$InputR_t = f(Kr_t, HCr_t, OutGeneR_t)$$

$$OutputR_t = f(RP_t)$$

$$Kr_t = f(OutGovtRFund_t, OutVCtoR_t)$$

$$HCr_t = f(PblKnow_t, TeAlR_t, EffectiveLr_t)$$

These equations are a function of other variables, most found within the rest of the modules composing the model and explained in detail later in this section. Where Kr_t represents the sum of all financial resources going to knowledge production and is itself in function of government funding for research, $OutGovtRFund_t$ and the levels of venture capital investment going to research,

¹³This flow is set in order to balance the levels of research potential, since these do not accumulate over time. This meaning that the mix of inputs used at a specific dt is a unique combination that produces (or not) a particular level of knowledge or information.

OutVCtoR_t. The variable *HCr_t* displays the levels of human capital available, which at the same time are in function of the available public knowledge *PblKnow_t*, the existing patented knowledge that has been transferred to research activities *TeAlR_t*,¹⁴ and the effective labor hand working on research that has access to such information within the existing research centers.¹⁵ The last component within this set of variables is the level of genetic resources *OutGeneR_t*, which represents the level of these resources used by the sector to discover information that can be transformed into new knowledge and later into innovations.

The second equation explains the dynamics of new knowledge as it moves from discovery to development (or further research) through technology transfer processes:

$$NRKA_t = \int_0^t (SuccessfulR_t - TechTrans_t) dt + NRKA_{t-1} \quad (3.2)$$

where *NRKA_t* is the new knowledge produced by research activities; *SuccessfulR_t* is the total number of successful research findings; *TechTrans_t* is the amount of new knowledge transferred through licensing at time *dt*; and *NRKA_{t-1}* is the initial stock of new knowledge.

The variables for this equation are:

$$SuccessfulR_t = f(AlProb_t, RP_t)$$

$$TechTrans_t = f(NRKA_t)$$

¹⁴The nomenclature used for this variable states that its value represents real numbers and not *Ln* levels.

¹⁵This suggests that the only labor hand that is accounted for in the sector is that which has a spot within the capacity of the existing research centers at time *dt*. This “infrastructure capacity” factor allows for the system to have a labor arbitrage mechanism, process that will be addressed in later sections.

where $A1Prob_t$ represents research's stochastic probability of success and all other variables have been previously addressed.

The dynamics within this module are essential for the entire system's performance, since it is at this stage where knowledge is first produced and transformed. Here a series of inputs are merged together into an easier to quantify and exchange unit referred to as "knowledge unit." Knowledge in this form not only becomes the central input/output of the entire model but also its currency; once knowledge units become transformed through the model's pricing mechanism (found within the *Resource Management* module), these allow for unit consistency throughout the entire system. Moreover, this transformation permits exploring how these units find their way from discovery to application and further up to becoming the primal inputs in the development processes of marketable innovations. Figure 3.2 provides a schematic representation of this first module.

These dynamics suggest that the financial resources encouraging research activities are the sum of venture capital and government funding. Human capital, on the other hand, is the sum of the effective labor force operating within the capacity of the existing research infrastructure having access to both the existing free-access information (in the form of public knowledge) and the information that becomes licensed back to research activities at any given time. Genetic resources also play a key role as the fundamental natural inputs from which information is extracted to produce new knowledge. As such, these require a use that balances their depletion and renewal rates. Although being a stock, *Research Potential* does not accumulate over time due to the fact that knowledge cannot be double per individual researcher. Meaning that, although knowledge has no decreasing returns to scale, if any individual has acquired certain knowledge,

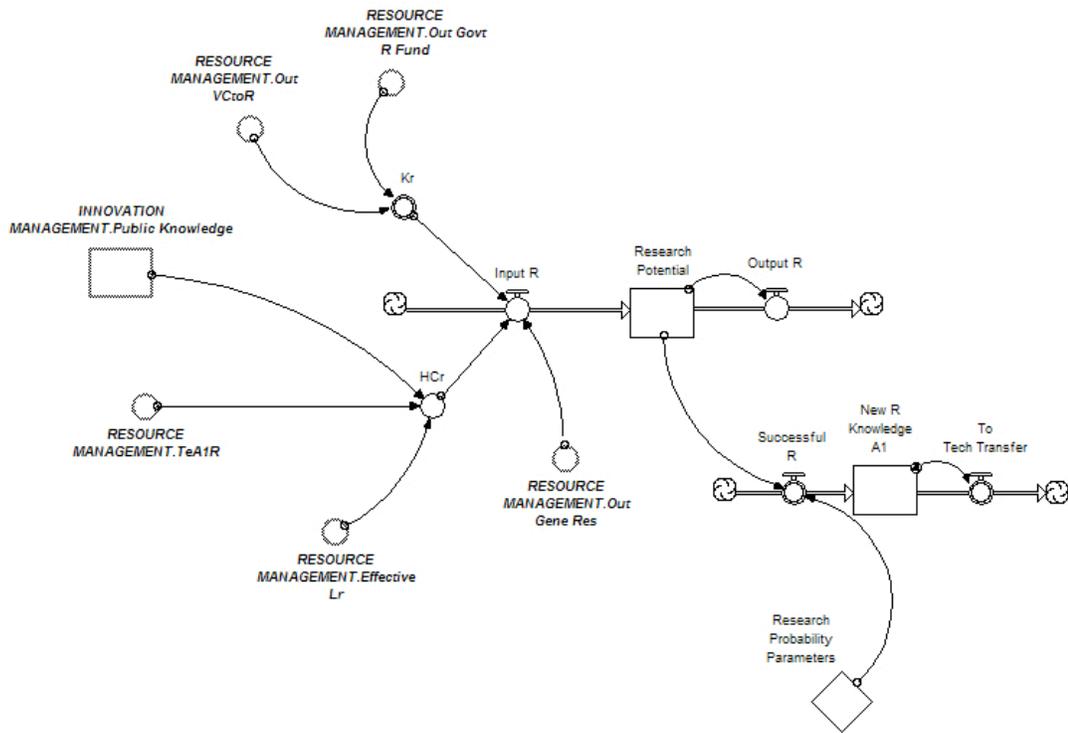


Figure 3.2: Research Module

learning about it again would provide her no additional value. Additionally, the module suggests that human capital adds value to the process only when individuals working in the sector have access to the information available to the sector at any given time. In other words, it requires that every individual working to achieve scientific discovery has a spot within the existing research infrastructure (which has limited capacity) or otherwise her value would be null to the process. Further, if the available infrastructure could not accommodate her, she would have to transfer to the development (production) process. As a consequence, this also requires balancing the formation of existing labor hand going to research and the growth in capacity of the existing infrastructure at any given time, which —as mentioned— can only accommodate a limited number of researchers at any given dt . This human capital mobility aspect of the model

attempts to capture Lucas' (1993) claim that the key to success of some newly industrialized countries is their ability to move more skilled workers quickly between activity sectors. In this case being research the fundamental sector and development the secondary. It also allows internalizing aspects of the labor mobility regulation existing within the EU framework.

It is also at this stage where the stochastic component of the model is first introduced (see figure 3.3). This mechanism—which determines the success or failure of research activities at any given dt inspired on Milling and Maier (2001)—bases its behavior on evolutionary biology principles in the following manner: the probability that *Research Potential* is successful changes as the levels of HCr and Kr change over time. In other words, the probability that *Research Potential* achieves a higher level of sophistication (evolves) and, thus becomes successful in producing new knowledge is directly proportional to the levels of change displayed by these two variables over time. More specifically, two Monte Carlo functions ($MTCK$ and $MTCHC$), each with a probability of success defined by the existing levels¹⁶ of HCr and Kr , respectively, are introduced here to produce a binary response (1 when successful, 0 when not) for each of these two variables at each dt .

The results generated by the Monte Carlo functions for each of these vari-

¹⁶In the general model the probabilities within the Monte Carlo functions $MTCK$ and $MTCHC$ were set to 40. At such level these distributions randomly generate either a 1 or a 0 with a mean number of occurrences per unit time of 40/100. However, this does not mean that the initial conditions for the variables HCr and Kr within the model are set at a level of 40; this figure (40) only represents an arbitrary level of development selected to represent the degree of sophistication of these variables in the analyzed systems. Furthermore, it has to be stated that although the changes affecting these levels vary in the same proportion (the probability of the Monte Carlo functions for each variable and the variables themselves), this does not mean that the actual levels of change for these are also the same. For example: If the level of Kr at $dt - 1$ within the model is 1,000 and increases to 1,200 by dt , then the probability of success for the Monte Carlo function for Kr within the stochastic mechanism of this module would increase in the same proportion, going from 40 to 48. This means a proportional increase of 20% in each. Yet, it does not mean that the level of change in both is the same, since for Kr it was 200 while for $MTCK$ only 8.

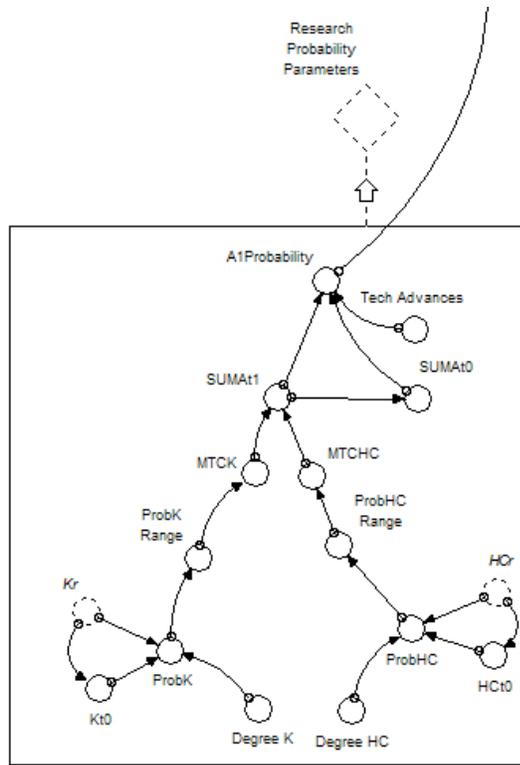


Figure 3.3: Research's Module Stochastic Component

ables at any given dt are then summed up and compared with the sum of these same for $dt - 1$.¹⁷ When compared, if the sum of results produced by the Monte Carlo functions for each variable at dt is higher than that at $dt - 1$, the process is considered to have evolved into a higher “state-of-the-art” and thus, *Research Potential* at dt is considered successful in its new research production capacity and above that of the previous $dt - 1$.¹⁸

¹⁷These results can either be: a) 2 when the Monte Carlo functions for each variable produce a successful outcome; b) 1 when only one of the Monte Carlo functions produces a successful outcome; or c) 0 when both Monte Carlo functions produce failing outcomes.

¹⁸*Research Potential* also moves forward when the sum of outcomes for *MTCK* and *MTCHC* at dt and those for these at $dt - 1$ are equal to 4. This suggests that *Research Potential* at dt displays the capacity to produce knowledge equal to that it had at $dt - 1$, therefore considering it successful. This introduces in the model the *Learning by Doing* effect suggested by Aghion and Howitt. By allowing the sector to move forward in cases when it displays equally as high knowledge production capacity as that of an immediate previous period suggests that innovation, in the second term, was achieved through secondary innovation. It is assumed, thus, that fundamental innovation allowed it to achieve the exemplar quality research potential levels in the initial term. In other words, both fundamental and secondary innovation activities allow

This mechanism, however, does not leave the advancement of research solely to chance, since —as mentioned— the Monte Carlo functions' probabilities of success also depend on the initial levels at which these are set. In later model versions these are defined by taking into account historic levels of human and financial capital allocated for research in each of the systems under scrutiny. Therefore, the pre-existing levels of these two variables also exert influence on the overall possibility of success. The degree of change that each of these two variables expresses every dt is applied to each of these initial levels, either increasing or reducing the subsequent probability of success for each of the Monte Carlo stochastic functions and, consequently, that of creating what in the model is defined as *New R Knowledge A1*. Therefore, in this model —like in any evolutionary biological process (i.e. genetic variation)— both random and non-random effects equally partake in defining the possibility of moving forward to a more developed stage which here translates into a more sophisticated knowledge finding process.

Development

This second module describes the process in which information obtained through basic research —along with various other inputs— becomes transformed into innovative products and services. It also shows the procedures these outputs go through in order to successfully reach the market. Like the knowledge and information creation mechanism, this module focuses on defining the levels of multiple stock: the overall system's development potential, the stock of new innovations created over time, and the degree of innovations turned into products or services currently on the market (see figure 3.4).

The equations for these stocks are defined as follows:

Research Potential to evolve into a more sophisticated production level.

$$DP_t = \int_0^t (InputD_t - OutputD_t) dt + DP_{t-1} \quad (3.3)$$

where DP_t is the system's overall development potential level as measured by a stock of inputs; $InputD_t$ is the sum of all inputs used in producing new innovation at time dt ; $OutputD_t$ represents the depletion of these inputs at time dt ,¹⁹ and DP_{t-1} is the existing development capacity.

The variables in this first equation:

$$InputD_t = f(Kd_t, HCd_t, NatResDep_t)$$

$$OutputD_t = f(DP_t)$$

$$Kd_t = f(InDReinvest_t, OutGovtDFund_t, OutVCtoD_t)$$

$$HC_t = f(PblKnow_t, TeA1D_t, EffectiveLd_t)$$

Like with research, these are mostly a function of other variables found within the multiple modules of the model.

where Kd_t represents the sum of all financial resources going to innovation activities and is itself in function of the sector's degree of reinvestment $InDReinvest_t$, government funding for development $OutGovtDFund_t$, and levels of venture capital investment going to development represented by $OutVCtoD_t$.

The variable HCd_t captures the human capital in the sector, which is — as well as that for research— in function of the available public knowledge

¹⁹Just as in the research module, this last flow is set in order to balance the levels of development potential, since these also do not accumulate over time. In this case meaning that the mix of inputs available at a specific dt is a unique combination that produces (or not) a particular level of innovation.

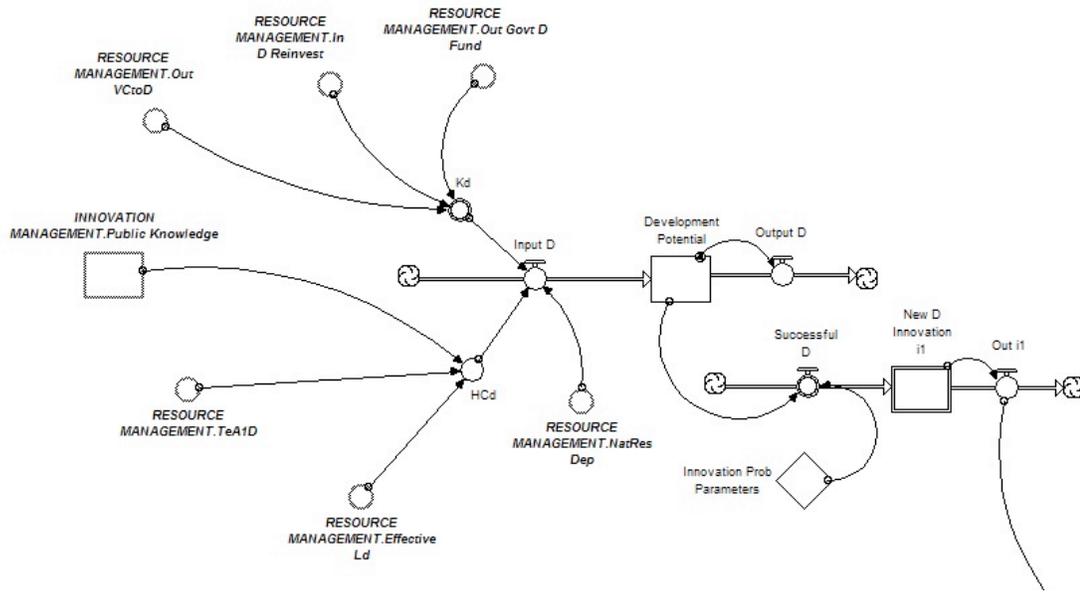


Figure 3.4: Development Module: First Two Stocks

$PblKnow_t$, the existing patented knowledge that has been transferred to development activities $TeA1D_t$,²⁰ and the effective labor hand working on creating the latest innovations having access to such information within the existing development centers and industries.²¹ Lastly the level of natural resources depleted $NatResDep_t$ is taken into account, which in the model represents the level of resources used (depleted) by the sector in its quest to transform knowledge and information into innovations. As opposed to research, the sector does not directly deal with genetic resources (although it can be argued that these are intrinsically accounted for within all natural resources). Instead, the use of raw materials and the effect that these transformation processes have on the environment are captured by this variable and displayed as a natural resources'

²⁰The nomenclature used for this variable also suggests that its value is in real numbers and not Ln levels.

²¹Then again, this also suggests that the only labor hand accounted for in the sector by the model is that which has a place within the capacity of the available development infrastructure at time dt . As mentioned, this 'infrastructure capacity' element allows the system to have a labor arbitrage mechanism.

depletion rate.

The second equation in this module focuses on how the system's development potential is consolidated into new products and services:

$$NDi1_t = \int_0^t (SuccessfulD_t - Outi1_t) dt + NDi1_{t-1} \quad (3.4)$$

where $NDi1_t$ is the level of new innovations produced by development activities; $SuccessfulD_t$ is the total number of successful innovations; $Outi1_t$ represents all new innovations that have market potential at dt ; and $NDi1_{t-1}$ is the initial stock of new innovation.

In particular, the variables in this equation are:

$$SuccessfulD_t = f(i1Prob_t, DP_t)$$

$$Outi1_t = f(NDi1_t)$$

where $i1Prob_t$ represents the stochastic probability of successfully developing innovations while $NDi1_{t-1}$ has been previously explained.

The dynamics and composition of this module are quite analogous to those of the *Research* module, especially when it comes to the evolutionary stochastic element defining the possibility of successfully developing a series of innovations with sufficient market potential (see figure 3.5). Echoing the dynamics of that module, the probability of innovation bases its logic on evolutionary biology principles; the chance that *Development Potential* is successful varies as the levels of HCd and Kd change over time. Then again, the likelihood that *Development Potential* achieves a more evolved level (progresses) and, therefore, becomes successful is directly proportional to the level of change that these two variables show over time, as well as to the initial levels defined for both Monte Carlo probabilities at $t = 0$.²²

²²Since the process is described in detail in the previous section I will not delve in its dynamics

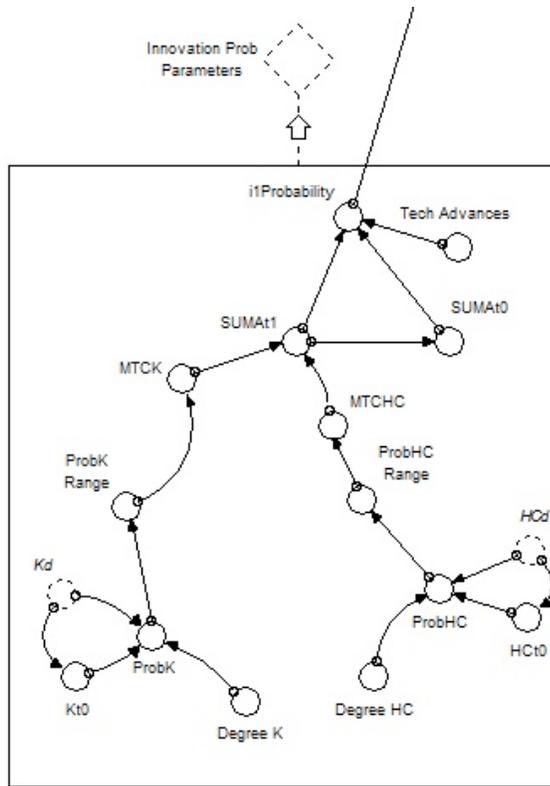


Figure 3.5: Development's Module Stochastic Component

The third equation in the module captures the stock of innovations currently on market at time dt (see figure 3.6). It is at this stage where those successful innovations with market potential face the existing regulatory guidelines overseeing environmental safety and innocuousness. Based on a dynamic probability that is in function of the level of resources allocated for biosafety and human health review processes at time dt , these new innovations either become part of the stock of new biotech products or services or become rejected. Particularly, rejection of these derives from to the impossibility of inspection due to low levels of resources required for either type of inspection.²³ The actual $InMarket_t$

here in order to avoid further descriptive redundancies.

²³This mechanism is based on a double Monte Carlo probability, each defining the chance of obtaining either a 1 (pass) or a zero (fail) for either of the regulatory processes. A bundle of successful 'innovations' reaching this flow require having a positive outcome in both probabilities in order to become part of the stock of *In Market* products. The degree at which these probabili-

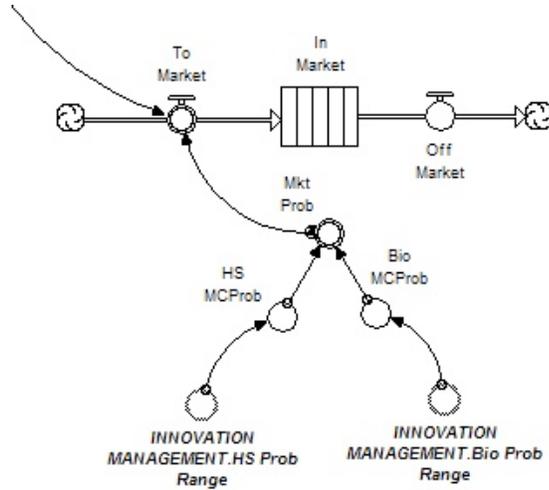


Figure 3.6: Development Module: In Market

stock works as a conveyor that holds these new products and services for a period of 5 years (or 10 dt in model's time) before allowing them to exit as these become obsolete and replaced by new innovations.

The equation for this segment is:

$$InMarket_t = \int_0^t (ToMarket_t - OffMarket_t) dt + InMarket_{t-1} \quad (3.5)$$

where $InMarket_t$ represents the stock of innovations in market at dt ; $ToMarket_t$ is the volume of new innovation produced by development activities entering the market at dt ; $OffMarket_t$ is the total of these that exit the market once becoming obsolete also at dt ; and $InMarket_{t-1}$ is the initial stock of products existing in the market.

Simultaneously, the variables:

$$ToMarket_t = f(Outi1_t, MktProb_t)$$

ties are set is defined by the amount of resources that each oversight mechanism has at dt , either increasing or reducing the chances of success. Both mechanisms are explained in more detail in the upcoming sections addressing the *Innovation Management* and *R&D Policy* modules.

$$OffMarket_t = f(InMarket_t)$$

are in function of other.

where $MktProb_t$ represents the new innovation's stochastic probability of successfully reaching the market after going through biosafety and human health reviews, while all other variables have already been explained. In particular the behavior of $ToMarket_t$ is represented by the following equation:

$$ToMarket_t = (Outil_t \cdot MktProb_t)$$

The variable $MktProb_t$ within this equation requires a deeper explanation; this variable is in function of two other variables — $BioMCProb_t$ and $HSMCProb_t$ — which, respectively, set the probabilities within the Monte Carlo functions for biosafety and health inspection.²⁴ These variables are —concurrently— in function of two other — $BioProbRange_t$ and $HSProbRange_t$ — designed exclusively to establish a range between 0 and 100 for the probabilities at the core of the previous two.²⁵ Lastly, these two variables setting the operational range are further in function of two more — $BioProbability_t$ and $HSProbability_t$ — which ultimately define the levels (numbers) that are used as probabilities within the Monte Carlo functions established by the $BioProbability_t$ and $BioProbability_t$ variables. These last two are defined within the biosafety and health inspection mechanisms described in the upcoming *Innovation Management* module. This whole set of interlinked variables is

²⁴The Monte Carlo functions within both $BioMCProb_t$ and $BioMCProb_t$ randomly generate a series of zeros or ones, based on a probability ultimately defined by the levels of $BioProbability_t$ and $HSProbability_t$ and within the range 0 and 100 established by $BioProbRange_t$ and $HSProbRange_t$. As explained previously, such levels represent the percentage probability of either passing (1) or failing (0) to comply with the biosafety or health inspection requirements per unit of simulation time. In order for a bundle of innovations to reach the market, the outcome of both Monte Carlo probabilities has to be 1.

²⁵This is due to the fact that, when using STELLA, the probability of a Monte Carlo statistical function that is evaluated to a number outside the 0 and 100 range, is automatically set to 0 by the program.

captured by the following functions:

$$MktProb_t = f(HSMCProb_t, BioMCProb_t)$$

and:

$$HSMCProb_t = f(HSProbRange_t)$$

$$BioMCProb_t = f(BioProbRange_t)$$

$$HSProbRange_t = f(HSProbability_t)$$

$$BioMCProb_t = f(BioProbability_t)$$

where $MktProb_t$ is the probability of new innovations reaching the market after being assessed by biosafety and health inspection services; $BioMCProb_t$ and $HSMCProb_t$ are the Monte Carlo functions defining the probability of successfully complying with the biosafety and health inspection requirements, respectively; $BioProbRange_t$ and $HSProbRange_t$ are the logical functions setting the range within which the probabilities for both Monte Carlo functions are different from 0²⁶; and $BioProbability_t$ and $HSProbability_t$ are the probability levels

²⁶The variables $HSProbability_t$ and $BioProbability_t$ are defined by the following logical algorithmic commands:

```

if  $HSProbability_t > 100$  then
     $HSProbability_t \leftarrow 100$ 
else
     $HSProbability_t \leftarrow HSProbability_t$ 

```

and:

```

if  $BioProbability_t > 100$  then
     $BioProbability_t \leftarrow 100$ 
else
     $BioProbability_t \leftarrow BioProbability_t$ 

```

These last two variables assure that the probability range of the two Monte Carlo probabilities controlling both biosafety and health inspection always remain between 0 and 100, a necessary condition for the appropriate performance of this type of statistical function. This is due to the

for each Monte Carlo function as defined within the model by the biosafety and health inspection mechanisms, respectively.

Innovation Management

This module details how the system copes with the results of both R&D activities by describing the dynamics of novel processes and institutional arrangements defined to bridge these two areas and to allow the results of innovation to enter the market system. It also focuses on explaining how the available infrastructure in both areas accommodates human capital engaged either in the production of new information or that of goods and services derived from modern biotech. The three sub-systems at the center of this module target: 1) the transferring and accessing of patented and public information; 2) the dynamics of both biosafety review processes and health safety inspection mechanisms; and 3) the behavior of existing R&D infrastructure as it harbors and allocates the available human capital.

A pivotal segment of this module explains how information is managed and how parts of it becomes either protected and privately exploited —through the use of patents— or publicly available within open-access information pools. This mechanism also explains how protected information is licensed by the research sector that produced it either to public and private industrial developers (innovation centers and firms) or back to research centers. Further, it captures the dynamics and effects stemming from cooperative activities in which organisms from either sector share information within physical or intangible clusters. The stocks devoted to information management represented within

fact that the biosafety and health inspection probability level may well dwell beyond this range and, thus, interfere with the appropriate functioning of the mechanism and that of the overall model. In upcoming sections both components, their levels, and sources will be explained in more detail.

this segment measure the level of patents, the level of these that —once their patents expire— become free-access knowledge, and the overall stock of public knowledge (see figure 3.7). These processes were developed and inspired by the notions and measurement of creative destruction, knowledge obsolescence, and knowledge spillovers in growth processes deeply studied by Caballero and Jaffe (1993).

The equations for the first two stocks within this sub-system represent the levels of patented knowledge and those of information becoming free-access as follows:

$$PatentA1_t = \int_0^t (InPatentA1_t - ToFreeA1_t)dt + PatentA1_{t-1} \quad (3.6)$$

and

$$FreeAccessA1_t = \int_0^t (ToFreeA1_t - ToPubKnow_t)dt + FreeAccessA1_{t-1} \quad (3.7)$$

where $PatentA1_t$ represents the stock of patented information at dt ; $InPatentA1_t$ is the flow of new information produced by research activities being transferred from *Research* and thus, patented at dt ; $ToFreeA1_t$ is the flow of free-access information moving into public knowledge pools once its patents expire at dt ; and $PatentA1_{t-1}$ is the initial stock of patents existing in the system.

In the second equation $FreeAccessA1_t$ represents the stock of patented information that becomes public when the patent period ends at dt ; $ToFreeA1_t$ is explained above; $ToPubKnow_t$ is the flow going to the already existing free-access information pools (in function of the levels of $FreeAccessA1_t$); and $FreeAccessA1_{t-1}$ is the initial stock of information with expired patent protection available within the system.

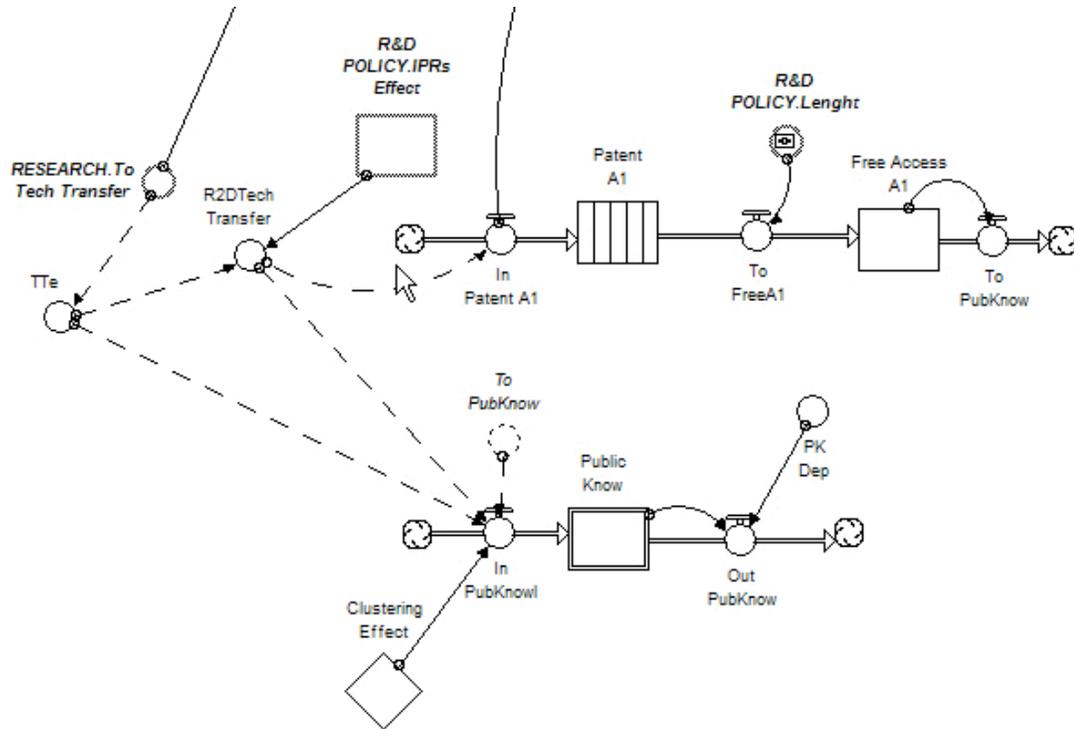


Figure 3.7: Innovation Module: Information Management Stocks

The variables in these flows are a function of:

$$InPatentA1_t = f(R2DTechTransfer_t)$$

$$ToFreeA1_t = f(Lenght_t)$$

and

$$ToPubKnow_t = f(FreeAccessA1_t)$$

Where $R2DTechTransfer_t$ represents the true levels of information (knowledge) transferred from research to development and is in function of both $IPREffect_t$, which shows the average level of protection that IPR regulation displays at dt^{27} , and TTe_t , which shows the degree of technology transfer in

²⁷The level of this variable represents a compound average composed by the breadth and length levels of IPR in the model at dt . Its detailed composition is addressed in the *R&D Policy* module.

real numbers. This last variable (TTe_t) serves as a temporary “translator” for $ToTechTransfer_t$, which provides the levels of technology transfer in Ln . This is due to the fact that the degree of technology transfer from research is multiplied by the level of protection that IPR regulation displays at dt to obtain the percentage of information that can subject to IPR regulation from that which cannot. Thus, establishing what percentage of this falls directly into public knowledge.²⁸ $Lenght_t$ displays the length of the patent as established by the IPR system within the *R&D Policy* module. Finally, $ToPubKnow_t$ is in function of the stock of existing free-access information (once patented information) going into the already existing open-access information pools.

The stock explaining the degree of public knowledge available in the system is expressed by the following equation:

$$PublicKnow_t = \int_0^t (InPublicKnow_t - OutPublicKnow_t)dt + PublicKnow_{t-1} \quad (3.8)$$

Where $PublicKnow_t$ is the stock of public information (knowledge) available at at dt ; $InPublicKnow_t$ represents the inflow of free information becoming public and is itself in function of multiple variables; $OutPublicKnow_t$ is the flow balancing the levels of public information stock, which set a depreciation rate at which information becomes available and, therefore, less novel; and $PublicKnow_{t-1}$ is the level of free access information at $dt - 1$.

In particular, the flows $InPublicKnow_t$ and $OutPublicKnow_t$ display the following functions:

$$InPublicKnow_t = f(ToPubKnow_t, TTe_t, R2DTechTransfer_t, ClusteringEffect_t)$$

²⁸Later, within the $R2DTechTransfer_t$ converter, the result of this operation is transformed back into Ln levels to be consistent with the flows going into the *PatentA1* stock.

and

$$OutPublicKnow_t = f(PKDepreciation_t)$$

Where $ToPubKnow_t$, $R2DTechTransfer_t$, and TTe_t have been previously explained and $ClusteringEffect_t$ is a decision mechanism which defines the information sharing rate within clustering initiatives when these are present in the model. This effect measures how a fraction of private information that is shared within these processes achieves an almost “quasi-public” degree inducing knowledge spillovers. Therefore, becoming part of the stock of public knowledge (see figure 3.8). In particular, this clustering trait is introduced in the model inspired on the views of representatives from Barcelona’s bioregion BioCat and those provided by researchers within the PRBB describing the effectiveness at the regional level of these collaborative initiatives.²⁹

The process describes the logical functions accounting for these spillovers when either research or development (or both) clusterings are available in the model as follows: The spillover levels in either research or development are defined by the variables $SpillRClust_t$ and $SpillDClust_t$, respectively. Since these variables are expressed in Ln terms, the levels of these are translated into natural numbers by the variables $eSRC_t$ and $eSDC_t$ which then become part of the logical functions that define the total spillover effects. Being both $RClustering_t$ and $DClustering_t$ two of the effects that can be induced in this model (later defined as ‘treatments’ in the experiment design section) these can be either “on” (1) or “off” (0) to display when these are present. In the case where both are off,

²⁹A clear example is captured in the opinion of an expert in bioinformatics and genomics from Cataluña who mentioned that “breaking away for traditional structures, these new configurations facilitate accessing funding and issuing more expedited decisions on hiring and going about research projects.” Other experts in Spain stated that clustering also induced the “creation of multiple public-private [research] initiatives as well as the establishment of ‘friendly’ competition.” This, in addition to “fostering collaboration between scientific parks and research centers among which the formation of highly skilled research groups happens.”

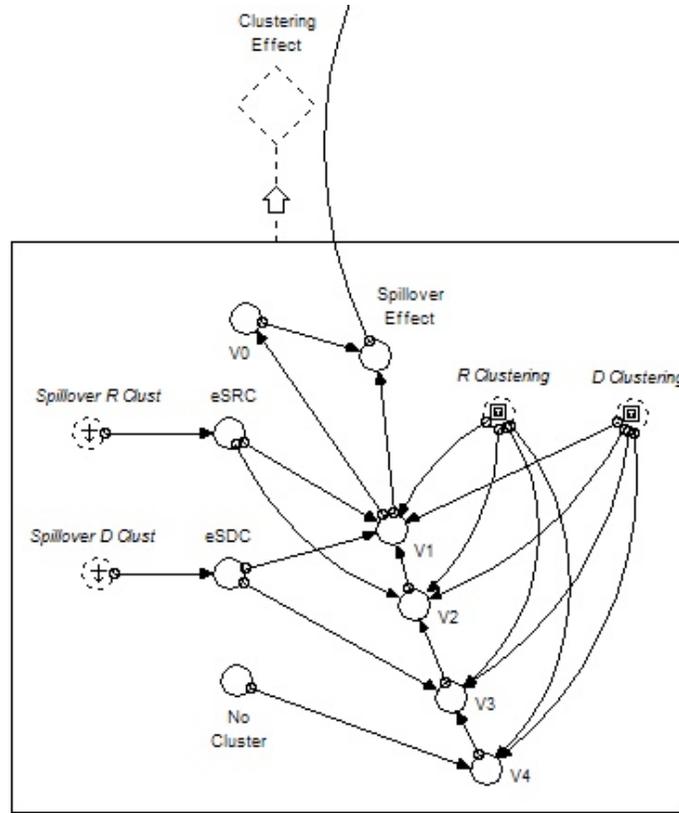


Figure 3.8: Clustering Effect Decision Process

the level of the variable $NoCluster_t$ within this process is set to be 0. The central variable in this process, $SpillEffect_t$, expresses the flow of spillovers that will be added to the information flow depending on a combination of the above mentioned factors and is in function of five variables — $V0_t$, $V1_t$, $V2_t$, $V3_t$, and $V4_t$ — each expressing a logical function.

The thread of logical functions these variables establish is the following:³⁰

$SpillEffect_t$:

if $V1_t = 1$ then

$V1_t \leftarrow 0$

³⁰The first two logical functions are defined to avoid calculating spillovers when the level of these is actually 0. This is due to the fact that any Ln term equal to 0 would be translated into 1 when transformed back to natural numbers. In other words, if the sum of $eSRC_t$ and $eSDC_t$ is 2 —when both clustering effects are present— or 1 —when only one of these is present— it can be inferred that the spillover effect for that dt is 0.

else
 $V1_t \leftarrow V0_t$

$V0_t$:

if $V1_t = 2$ **then**
 $V1_t \leftarrow 0$

else
 $V1_t \leftarrow V1_t$

$V1_t$:

if $RClustering_t = 1$ **and**
 $DClustering_t = 1$ **then**
 $V1_t \leftarrow (eSRC_t + eSDC_t)$

else
 $V1_t \leftarrow V2_t$

$V2_t$:

if $RClustering_t = 1$ **and**
 $DClustering_t = 0$ **then**
 $V2_t \leftarrow (eSRC_t)$

else
 $V2_t \leftarrow V3_t$

$V3_t$:

if $RClustering_t = 0$ **and**
 $DClustering_t = 1$ **then**
 $V3_t \leftarrow (eSDC_t)$

else
 $V3_t \leftarrow V4_t$

and:

$V4_t$:

if $RClustering_t = 0$ **and**

DClustering_t = 0 **then**
V4_t ← *NoCluster_t*
else
V4_t ← 0

Lastly for this segment, the variable *PKDepreciation_t* represents the rate at which the stock of free-access information loses novelty and is defined as:

$$PKDepreciation_t = e^{-0.02 \cdot t}$$

This depreciation rate, however, does not imply diminishing returns in the utility of information in a pure neoclassical sense, instead it tries to capture a reduction in novelty once it becomes public.

The second part within this section details the information transferring process as well as the actual levels of clustering when these scenarios are present. There are two pairs of stock at the center of this mechanism, depending on whether clustering is available or not in the model (see figure 3.9). In the case when clustering is not available these are: the level of information licensed to development and that licensed back to research. The equations for these two central stocks are:

$$LicensedR_t = \int_0^t (InLicR_t - OutA1R_t)dt + LicensedR_{t-1} \quad (3.9)$$

and

$$LicensedD_t = \int_0^t (InLicD_t - OutA1D_t)dt + LicensedD_{t-1} \quad (3.10)$$

Where *LicensedR_t* is the stock of available information (knowledge) protected through IPR schemes licensed for research activities at *dt*; *InLicR_t* represents the inflow of protected information coming from *Research* into the stock of licensed knowledge going to research, which is itself in function of the fraction

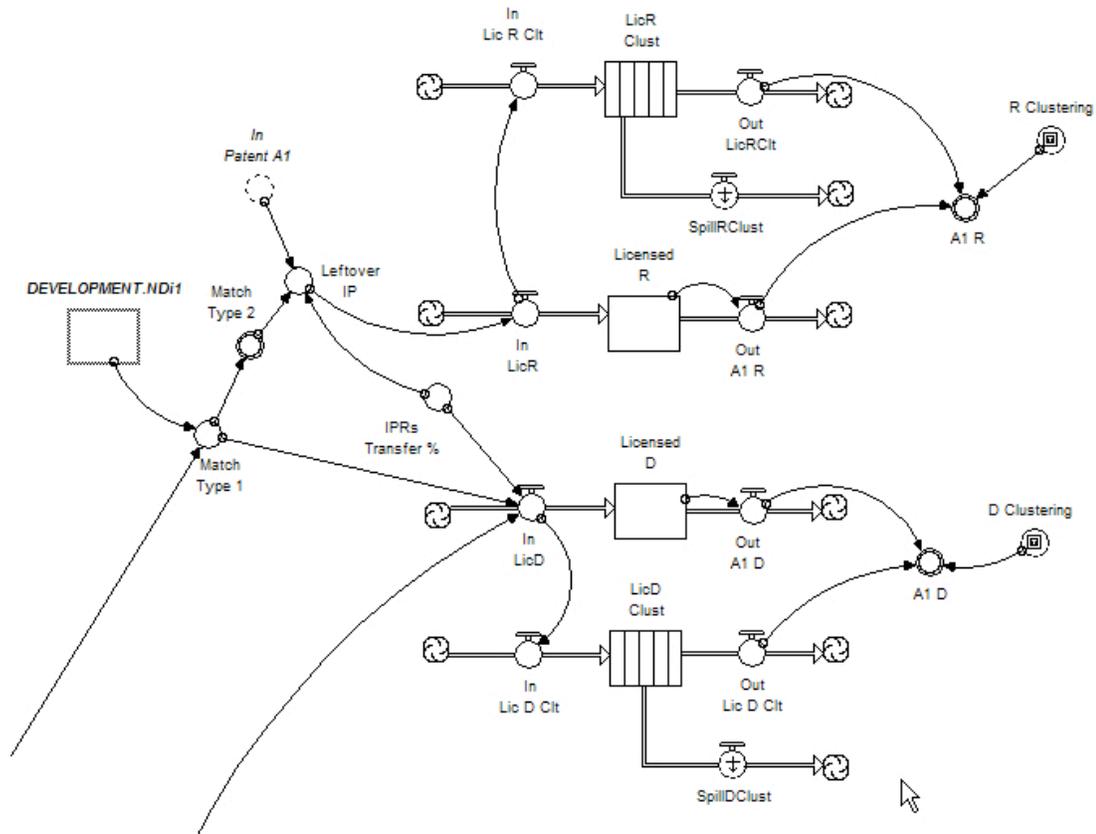


Figure 3.9: Information Transferring and Clustering Process

of the stock of available information that has not been licensed to development (more on this later); $OutA1R_t$ is the actual outflow of protected information that loops back to research activities and balances the stock of protected information for these; and $LicensedR_{t-1}$ is the level of protected information for research at $dt - 1$. For the second equation, $LicensedD_t$ is the stock of IPR protected information licensed to development and innovation industries at dt ; $InLicD_t$ represents the inflow of protected information coming from *Research* into the stock of licensed knowledge going to development, which is itself in function of other variables (that will also be explained in short); $OutA1D_t$ is the outflow of protected information going to development activities and balancing the levels of available stock transferred to innovation; and $LicensedD_{t-1}$ is the quantity of

available protected information for development at $dt - 1$.

The mechanism setting the levels at which information within the model is transferred either to research or development is inspired by the “match-making” processes provided by particular agents within Spain’s MBTS. As described by various interviewed actors, these serve —among other things— as ‘knowledge brokers’ for specific productive or research sectors and thus, play a key role in bridging the gap between basic and applied endeavors. Institutions like *Genoma España* at the national level, BioCat and *Madrid Bio* at the regional, and particular offices within the PRBB and PCB are examples of institutions offering these types of services. The design of this mechanism also took into account other views provided by representatives of the Cataluña biomedical research park and the EBF on the limitations that these systems have so far displayed. In particular, it considers those relative to the effects of development’s reduced demand for new knowledge and low commercial value patents.

In this process a set of logical functions allows for any available information produced by the research sector that can be protected through IPRs to be immediately allocated within development activities when the latter sector’s innovation stock displays low levels. This also allows for any residual information to be allocated within research whenever it is not directly supplied to development activities. The process happens within the two inflows going either to research or development, which are explained by the following set of functions:

$$InLicD_t = f(InPatentA1_t, IPRTtransfer\%_t, MatchType1_t)$$

$$InLicR_t = f(LeftoverIP_t)$$

and

$$MatchType1_t = f(NDi1_t)$$

$$MatchType2_t = f(MatchType1_t)$$

$$LeftoverIP_t = f(InPatentA1_t, MatchType2_t)$$

Where $InLicR_t$ and $InLicD_t$ represent the inflows going to $LicensedR_t$ and $LicensedD_t$ stocks and are represented by the following algebraic and logical functions, respectively:

$$InLicR_t = LeftoverIP_t$$

and

$InLicD_t$:

if $MatchType1_t = 1$ **then**

$$MatchType1_t \leftarrow InPatentA1_t$$

else

$$MatchType1_t \leftarrow (IPRTransfer\%_t) \times (InPatentA1_t)$$

While $InPatent_t$ has been previously explained, the variable $IPRTransfer\%_t$ represents a fixed fraction at which new knowledge is commonly transferred from research to development. Yet, since it is practically impossible to establish such “transfer degree” the value of this variable is set to 0, suggesting that when there is no match-making process, the connection between research and development is equally impossible to define.³¹

Further, $MatchType1_t$ defines the fraction of patented new knowledge that goes to development and operates through the following logical function:

$MatchType1_t$:

if $NDi1_t < 1$ **and** $ToTechTransfer_t > 0$ **then**

³¹This last notion is introduced in the model to capture the notion that, by its very definition, scientific activity is a risky process which output cannot be predicted perfectly from its inputs suggested by Arrow (1959). Thus, justifying all match-making endeavors (and the inclusion of these in the general model). However, in the general model this fraction can be arbitrarily defined in the absence of the match-making process. Future research could assist in defining proxies of this fraction for different R&D areas.

```

    MatchType1t ← 1
else
    MatchType1t ← 0

```

This process allows for the results of research activities —when available— to be transferred to development when the stock of new innovations within that module are low (meaning that when the system’s development potential has not been able to successfully produce new innovations, due in part to its stochastic component, its demand for new knowledge increases). Conversely, *MatchType2_t* and *LeftoverIP_t* set a mechanism that allows for new knowledge that was not allocated to development —because the sector successfully produced innovations at *dt*— to loop back into research for its use through the following logical functions:

```

MatchType2t:
    if MatchType1t = 1 then
        MatchType2t ← 0
    else
        MatchType2t ← 1

```

and

```

LeftoverIPt:
    if MatchType2t = 1 then
        LeftoverIPt ← InPatentA1t
    else
        LeftoverIPt ← IPRTtransfer%t

```

Last, both outflows *OutA1R_t* and *OutA1D_t* coming from the main *LicensedR_t* and *LicensedD_t* stocks connect to two converters: *A1R_t* and *A1D_t*. These converters, which capture the total level of new knowledge transferred to either research or development, are explained in detail in the next segment.

For the case when clustering is available, the equations defining the pair of stocks at the center of the process are:

$$LicRClust_t = \int_0^t (InLicRCl_t - OutLicRCl_t - SpillRClust_t) dt + LicRClust_{t-1} \quad (3.11)$$

and

$$LicDClust_t = \int_0^t (InLicDCl_t - OutLicDCl_t - SpillDClust_t) dt + LicDClust_{t-1} \quad (3.12)$$

Where $LicRClust_t$ and $LicDClust_t$ are the stock of information available when clustering is present; $InLicRCl_t$ and $InLicDCl_t$ are the flows of information coming into the clustering conveyors at dt and are equal to $InLicR_t$ and $InLicD_t$, respectively; $OutLicRCl_t$ and $OutLicDCl_t$ are each the contents of outflow slats of information exiting each conveyor every $3 dt$; $LicRClust_{t-1}$ and $LicDClust_{t-1}$ are the initial levels of each conveyor at $dt - 1$; and $SpillRClust_t$ and $SpillDClust_t$ represent the fraction of information “leaking” every dt from either conveyor and are both set to be 40% of the available stock. As suggested, these stocks work as conveyors that, instead of holding information for one period, hold new information for a period of 3 years (or $6 dt$ in model’s time) before allowing it to flow out of the system. The logic behind this process is that information —when shared— displays a “multiplicative effect” quite similar to that of free-access information, allowing whatever sector that incurs in clustering to add such level of information to its stock for a longer period of time (beyond the conventional one period benefit when no clustering is present). Furthermore, when patented new information becomes shared within a cluster it produces a series of spillovers that are added to the stock of public-access information for

as long as the information remains within these conveyors. This process further introduces in the general model the quasi-public good nature of information suggested in Arrow (1959); Romer (1990); Jones and Romer (2009).

Finally for this segment, just as in the previous no-clustering case, the two outflows coming from these conveyors $OutLicRClt_t$ and $OutLicDClt_t$ connect to the $A1R_t$ and $A1D_t$ converters. Also connecting to these converters are other two, $RClustering_t$ and $DClustering_t$, which hold the commands that signal if the model's clustering capacity for either sector is turned on or off. Following a series of logical commands, the former converters display the appropriate level of new knowledge transferred to either sector depending on what the latter converters express about clustering. These commands are:

$A1R_t$:

```

if  $RClustering_t = 1$  then
     $RClustering_t \leftarrow OutLicRClt_t$ 
else
     $RClustering_t \leftarrow OutA1R_t$ 

```

and

$A1D_t$:

```

if  $DClustering_t = 1$  then
     $DClustering_t \leftarrow OutLicDClt_t$ 
else
     $DClustering_t \leftarrow OutA1D_t$ 

```

The third and fourth subsystems, respectively, explain how biosafety and health safety are introduced into the general model and managed within this module. The first of these subsystems captures commonalities found between the processes described within the biosafety regulatory frameworks of Spain (EU Directives 2009/41/EC and 2000/54/EC and Ley 9/2003; Real Decreto

178/2004) and Mexico (*Biosafety of Genetically Modified Organisms Law* and its *Reglamento*). Therefore, it considers the important role that these newly minted commissions on biosafety have played in the advancement of modern biotech in both nations, as suggested by the various actors operating in these systems.³²

However, more than describing the operation of a central biosafety commission, this mechanism depicts the dynamics behind the network of institutions engaged in this type of review processes hired by this agency (see figure 3.10).

In particular, the biosafety process is defined by two stocks with equations:

$$BioIndRes_t = \int_0^t (InBioInd_t - BioIndtoGovt_t)dt + BioIndRes_{t-1} \quad (3.13)$$

and

$$BioProb_t = \int_0^t (InProb_t - OutProb_t)dt + BioProb_{t-1} \quad (3.14)$$

Where $BioIndRes_t$ represent the stock of resources available for biosafety review processes at dt ; $InBioInd_t$ is the flow of resources coming to biosafety from the industry at dt ; $BioIndtoGovt_t$ is the outflow of resources coming from the available stock at dt and defined by a logical function. This last flow is considered a tax paid by the innovation sector to achieve certification for new products and services and, as so, goes to the stock of government resources within the *Resource Management* module; $BioIndRes_{t-1}$ is the stock of biosafety

³²This becomes clear in the views of a representative of the bio-pharma industry in Spain who declared that “since the European Council adopted its first directives on marketing high-technology medical products —specially those deriving from modern biotech— made evident the need for a centralized authorization procedure that is compulsory for these types of products. Furthermore, this now centralized evaluation procedure is helping establish higher levels of scientific evaluation for these new products within the EU, especially at a time when the perception and confidence in the evaluation process of patients and medical professionals is key for their success and prompt approval.” The relevance of these institutions is also captured in the opinion of a representative of Mexico’s biosafety commission, who declared that “even before having judicial character, the commission helped promote the enacting of the current biosafety of GMOs regulation. Serving also as model for other developing nations pursuing the advancement of these technologies.”

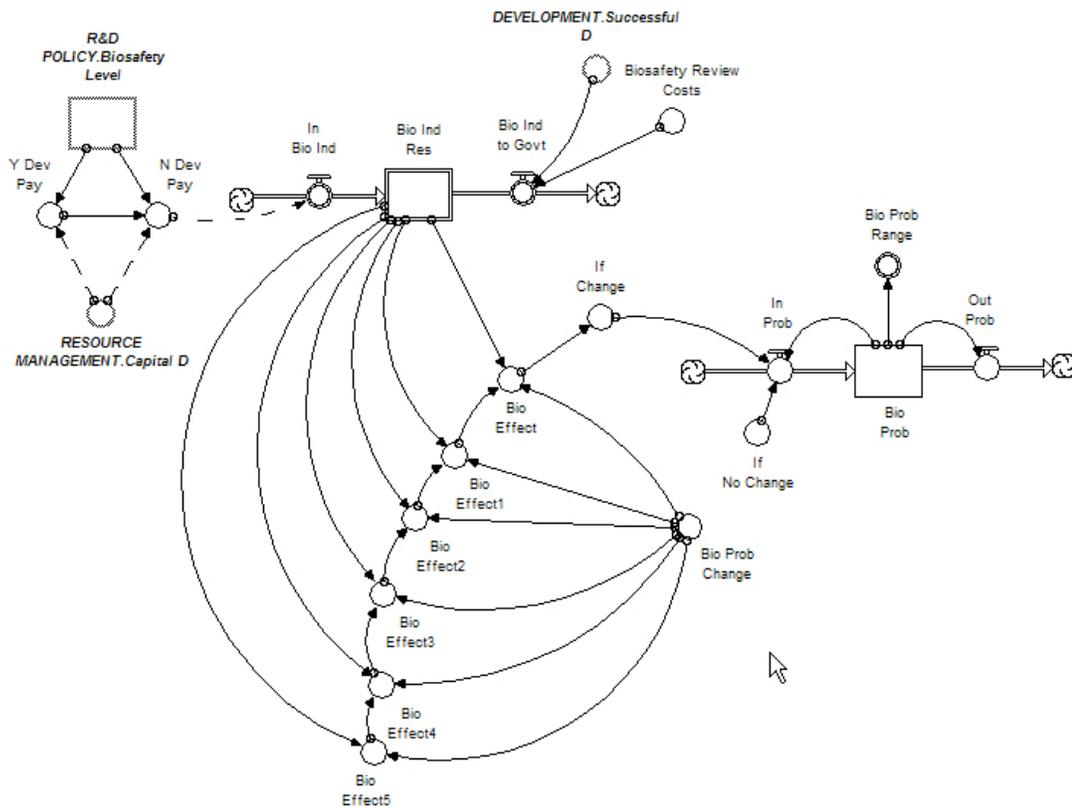


Figure 3.10: Biosafety Process

resources at $dt - 1$. For the second equation $BioProb_t$ represents the probability of the Monte Carlo statistical function that defines whether a batch of new innovations comply with biosafety levels at dt . Its initial stock level is set to be 80; $InProb_t$ defines how the probability of success defined by the $BioProb_t$ stock changes overtime. This flow is in function of a set of logical functions which define the actual degree of change (explained later); $OutProb_t$ is the outflow that balances the probability levels each dt ; and $BioProb_{t-1}$ is the probability level at $dt - 1$.

The variables $InBioInd_t$ and $BioIndtoGovt_t$ display the functions:

$$InBioInd_t = f(NDevPay_t)$$

and

$$BioIndtoGovt_t = f(BiosafetyReviewCosts_t, SuccessfulD_t)$$

Where $InBioInd_t$ is equal to $NDevPay_t$; $NDevPay_t$ represents no payment from the innovation industry to biosafety and is part of a logical function scheme that sets the degree at which the inflow of resources coming to biosafety activities varies over time. This variable is itself in function of: $YDevPay_t$, $BiosafetyLevel_t$, and $CapitalD_t$. More specifically, the process these variables engage in is composed as follows:

$NDevPay_t$:

if $CapitalD_t = 0$ **then**

$$NDevPay_t \leftarrow (0 \times BiosafetyLevel_t) \times CapitalD_t$$

else

$$NDevPay_t \leftarrow YDevPay_t$$

and

$YDevPay_t$:

if not $CapitalD_t = 0$ **and** $CapitalD_t < 1,000$ **then**

$$YDevPay_t \leftarrow (0.5 \times BiosafetyLevel_t) \times CapitalD_t$$

else

$$YDevPay_t \leftarrow (BiosafetyLevel_t \times CapitalD_t)$$

The two propositions at the center of this process suggest that the amount the industry pays for biosafety services depends on the amount of capital that the sector generates every dt ; the enforceable burden percentage—set at 10% of $CapitalD_t$ —is required by law when the sector's earnings are above a certain level (in this case when $CapitalD_t > 1000$). Conversely, only half of this tax is required when earnings are below the threshold and no payment is due if at any given dt the industry produces no capital. The Presence of capital earnings

(or lack of these) implies that the sector was successful (or not) in producing new biotech innovations and thus, requiring biosafety review for these before they can enter the market.

The variable $BioIndtoGovt_t$ is in function of, $BiosafetyReviewCosts_t$ which represents the costs of biosafety review per batch of new innovation produced at dt , set in the model at a price of 10,000,³³ while $SuccessfulD_t$ has been previously explained within the *Development* module. Using these variables $BioIndtoGovt_t$ defines the following logical function also suggesting that the industry incurs in biosafety expenses only when new biotech innovations with market potential are developed:

$BioIndtoGovt_t$:

if $SuccessfulD_t > 0$ **then**

$BioIndtoGovt_t \leftarrow BiosafetyReviewCosts_t$

else

$BioIndtoGovt_t \leftarrow 0$

The variables in the flows and converters to and from $BioProb_t$, on the other hand, display the functions:

$$InProb_t = f(IfChange_t, IfNoChange_t, BioProb_t)$$

and

$$OutProb_t = f(BioProb_t)$$

Where $InProb_t$ is the degree at which $BioProb_t$ changes each dt and is defined through a logical function which uses the values characterized by the $IfChange_t$ and $IfNoChange_t$ converters as well as the level of the stock

³³The knowledge-units-to-price process is later explained within the *Resource Management* module.

$BioProb_t$ to do so; $IfChange_t$ is the last echelon of a thread of logical functions defining the actual fraction of change; $IfNoChange_t$ is a constant fraction of change set at 0.5; and $OutProb_t$ balances $BioProb_t$ allowing it to change every dt .

The logical command defined by $InProb_t$ is:

$InProb_t$:

```

if  $IfChange_t > 0$  then
     $InProb_t \leftarrow (BioProb_t + IfChange_t)$ 
else
     $InProb_t \leftarrow (BioProb_t - IfNoChange_t)$ 

```

As mentioned, the variable $IfChange_t$ is atop of a thread of logical functions, which associates six converters — $BioEffect_t$, $BioEffect1_t$, $BioEffect2_t$, $BioEffect3_t$, $BioEffect4_t$, and $BioEffect5_t$ —, the stock $BioIndRes_t$, and the constant (set at 1) defined by the converter $BioProbChange$. This logical functions thread is:

$IfChange_t$:

```

if  $BioEffect_t > 0$  then
     $IfChange_t \leftarrow BioEffect_t$ 
else
     $IfChange_t \leftarrow 0$ 

```

$BioEffect_t$:

```

if  $BioIndRes_t = 0$  then
     $BioEffect_t \leftarrow (BioProbChange_t \times BioIndRes_t)$ 
else
     $BioEffect_t \leftarrow BioEffect1_t$ 

```

$BioEffect1_t$:

```

if  $BioIndRes_t > 10,000,000$  then

```

$BioEffect1_t \leftarrow BioProbChage_t$
else
 $BioEffect1_t \leftarrow BioEffect2_t$

BioEffect2_t:

if not $BioIndRes_t > 10,000,000$ **or** $BioIndRes_t = 0$ **and**
 $BioIndRes_t > 5,000,000$ **then**
 $BioEffect2_t \leftarrow (0.5 \times BioProbChage_t)$
else
 $BioEffect2_t \leftarrow BioEffect3_t$

BioEffect3_t:

if not $BioIndRes_t > 5,000,000$ **and** $BioIndRes_t > 2,500,000$
then
 $BioEffect3_t \leftarrow (0.25 \times BioProbChage_t)$
else
 $BioEffect3_t \leftarrow BioEffect4_t$

BioEffect4_t:

if not $BioIndRes_t > 2,500,000$ **and** $BioIndRes_t > 1,000,000$
then
 $BioEffect4_t \leftarrow (0.1 \times BioProbChage_t)$
else
 $BioEffect4_t \leftarrow BioEffect5_t$

BioEffect5_t:

if not $BioIndRes_t > 1,000,000$ **and** $BioIndRes_t > 100,000$
then
 $BioEffect5_t \leftarrow (0.05 \times BioProbChage_t)$
else
 $BioEffect5_t \leftarrow 0$

Each of these "effects" displays a level of change affecting the overall probability of passing biosafety inspection. The degree of these, concurrently, is in

function of the potential value (in price levels) that a series of successful innovations has at any given dt .³⁴

Lastly within this biosafety process, the converter $BioProbRange_t$ defines the probability set by the stock $BioProb_t$ in order to keep it within the 0 to 100 range required for the Monte Carlo stochastic process $BioMCProb_t$ within the *Development* module to operate. This is achieved through the following logical function:

```
BioProbRanget:  
    if BioProbt > 100 then  
        BioProbRanget ← 100  
    else  
        BioProbRanget ← BioProbt
```

The subsystem defining health inspection services operates in an analogous way to that of biosafety. This mechanism is also inspired on the processes described within the multiple health inspection regulations operating in Spain (Regulation (EC) 726/2004; Ley 29/2006; Decretos Reales 1345/2007; and 1201/2005) and Mexico (General Health Law and its multiple *Reglamentos*). It also captures the relevance of the role that central agencies in charge of health inspection services have, as pointed out by both representatives of the EFB, Spain's bio-pharma industry and Mexico's agriculture ministry, CIBIOGEM, and CONACyT.³⁵ However, this segment of the model depicts the dynamics

³⁴The levels of potential value displayed for $BioIndRes_t$ as well as the proportions by which $BioProbChage_t$ is multiplied within each converter are those used later on to assess the behavior of both the models representing the cases of Mexico and Spain. These are set at equal levels due to the fact that both countries abide to practically the same international biosafety norms, and because their local regulatory frameworks are mostly based on these norms.

³⁵This is captured perfectly in the words of a representative of Spain's bio-pharma sector who stated that "the [recently created] European Medicines Agency can now supervise the operation of the pharmaceuticals sector more effectively, as it is becoming the motor behind new gene and cell therapies throughout Europe."

behind the network of institutions engaged in these type of review processes and not on that of the specific central agencies themselves (see figure 3.11).

In this case the two equations at the center of the process are:

$$HealthSFund_t = \int_0^t (InHSFund_t - OutHSFund_t)dt + HealthSFund_{t-1} \quad (3.15)$$

and

$$HSProb_t = \int_0^t (InHSProb_t - OutHSProb_t)dt + HSProb_{t-1} \quad (3.16)$$

Where *HealthSafeFund_t* represents the stock of resources available for health inspection services processes at *dt*; *InHSFund_t* is the flow of resources coming to health inspection services from the industry at *dt*; *OutHSFund_t* is the outflow of resources coming from the available stock when health inspection is required at *dt*, defined by a logical function. This last flow, instead of being considered a tax (like biosafety is) is framed by a payment made by the innovation sector to independent safety review service providers (such as laboratories) to achieve a quality standard required for new products and services for human or animal use; *HealthSFund_{t-1}* is the stock of health inspection service resources at *dt - 1*. The second equation *HSProb_t* is the probability of the Monte Carlo statistical function that defines whether a cluster of new innovations comply with the health inspection levels at *dt*. The initial level for this stock is set to 75; *InHSProb_t* defines how the probability of success, given by the *HSProb_t* stock, changes overtime. This flow is also in function of a set of logical functions which define the actual degree of change (explained later); *OutHSProb_t* is the outflow that balances the probability levels each *dt*; and *HSProb_{t-1}* is the probability level at *dt - 1*.

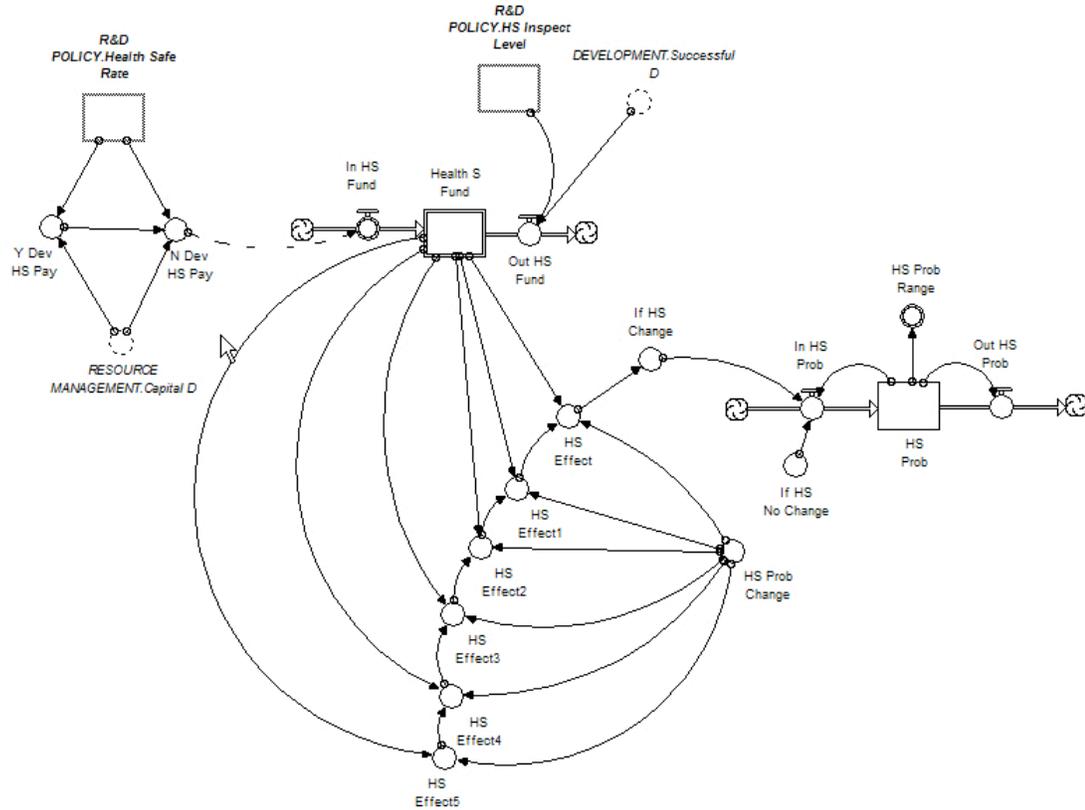


Figure 3.11: Health Inspection Process

The variables $InHSFund_t$ and $OutHSFund_t$ display the functions:

$$InHSFund_t = f(NDevHSPay_t)$$

and

$$OutHSFund_t = f(HSInspectLevel_t, SuccessfulD_t)$$

Where $InHSFund_t$ is equal to $NDevHSPay_t$; $NDevHSPay_t$ represents no payment from the innovation industry to health services and is part of a logical function scheme that sets the degree at which the inflow of resources coming to health inspection activities vary over time. This variable is itself in function of: $YDevHSPay_t$, $HealthSafeRate_t$, and $CapitalD_t$. The process described by these variables is composed as:

$NDevHSPay_t$:

if $CapitalD_t = 0$ **then**

$NDevHSPay_t \leftarrow (0 \times HealthSafeRate_t) \times CapitalD_t$

else

$NDevHSPay_t \leftarrow YDevHSPay_t$

and

$YDevHSPay_t$:

if not $CapitalD_t = 0$ **and** $CapitalD_t < 1,000$ **then**

$YDevHSPay_t \leftarrow (0.5 \times HealthSafeRate_t) \times CapitalD_t$

else

$YDevHSPay_t \leftarrow (HealthSafeRate_t \times CapitalD_t)$

The two propositions in this process suggest as well that the amount the industry pays for health services depends on the amount of capital generated every dt ; the enforceable percentage of income devoted to these services is set at 15% of $CapitalD_t$ and is also required by law when the sector's earnings are above a determinate level (in this case when $CapitalD_t > 1,000$). So as for biosafety, the required income percentage when earnings are below this threshold is half (7.5%) and no payment is required if there are no innovations to review at dt , meaning that the industry generated no capital. Analogous to the biosafety process, the presence of capital earnings (or lack of these) also implies that the sector was successful (or not) in producing new biotech innovations and, thus, requiring health safety review for these before these can enter the market.

The flow $OutHSFund_t$, in function of $HSInspectLevel_t$, represents the costs of these review procedures per output of new innovation produced at dt . Being more specific than those required by biosafety, these are set at a price of 200,000. $SuccessfulD_t$ has been addressed earlier. Using these variables, $OutHsFund_t$

defines the following logical function explaining how the industry invests in health safety when it produces new biotech innovations with market potential:

OutHSFund_t:

```

if SuccessfulDt > 0 then
    OutHSFundt ← HSInspectLevelt
else
    OutHSFundt ← 0

```

Alternatively, the variables in the flows and converters to and from *HSProb_t* have the functions:

$$InHSProb_t = f(IfHSChange_t, IfHSNoChange_t, BioProb_t)$$

and

$$OutProb_t = f(HSProb_t)$$

Where *InHSProb_t* is the degree at which *HSProb_t* changes each *dt* and is also defined through a logical function that uses the values expressed by the converters *IfHSChange_t* and *IfHSNoChange_t*, as well as the level of the stock *HSProb_t*, to do so; *IfHSChange_t* is the last link of a thread of logical functions defining the fraction of change; *IfHSNoChange_t* is again a fraction of change set at a constant 0.5; and *OutHSProb_t* balances *HSProb_t* allowing it to produce a different level every *dt*. The logical command defined by *InHSProb_t* is:

InHSProb_t:

```

if IfHSChanget > 0 then
    InHSProbt ← (HSProbt + IfHSChanget)
else
    InHSProbt ← (HSProbt - IfHSNoChanget)

```

The thread of logical functions headed by the variable $IfHSChange_t$ also associates six converters — $HSEffect_t$, $HSEffect1_t$, $HSEffect2_t$, $HSEffect3_t$, $HSEffect4_t$, $HSEffect5_t$ —, the stock $HealthSFund_t$, and the constant (fixed at 1) defined by the converter $HSProbChange$. This set of logical functions thread is:

$IfHSChange_t$:

```

if  $HSEffect_t > 0$  then
     $IfHSChange_t \leftarrow HSEffect_t$ 
else
     $IfHSChange_t \leftarrow 0$ 

```

$HSEffect_t$:

```

if  $HealthSFund_t = 0$  then
     $HSEffect_t \leftarrow (HSProbChange_t \times HealthSFund_t)$ 
else
     $HSEffect_t \leftarrow HSEffect1_t$ 

```

$HSEffect1_t$:

```

if  $HealthSFund_t > 10,000,000$  then
     $HSEffect1_t \leftarrow HSProbChange_t$ 
else
     $HSEffect1_t \leftarrow HSEffect2_t$ 

```

$HSEffect2_t$:

```

if not  $HealthSFund_t > 10,000,000$  or  $HealthSFund_t = 0$  and
 $HealthSFund_t > 9,000,000$  then
     $HSEffect2_t \leftarrow (0.75 \times HSProbChange_t)$ 
else
     $HSEffect2_t \leftarrow HSEffect3_t$ 

```

$HSEffect3_t$:

```

if not  $HealthSFund_t > 9,000,000$  and  $BioIndRes_t > 8,000,000$ 
then

```

$HSEffect3_t \leftarrow (0.5 \times HSProbChage_t)$
else
 $HSEffect3_t \leftarrow HSEffect4_t$

$HSEffect4_t$:

if not $HealthSFund_t > 8,000,000$ **and** $HealthSFund_t > 7,000,000$
then
 $HSEffect4_t \leftarrow (0.25 \times HSProbChage_t)$
else
 $HSEffect4_t \leftarrow HSEffect5_t$

$HSEffect5_t$:

if not $HealthSFund_t > 7,000,000$ **and** $HealthSFund_t > 6,000,000$
then
 $HSEffect5_t \leftarrow (0.05 \times HSProbChage_t)$
else
 $HSEffect5_t \leftarrow 0$

Once again, each of these effects shows a degree of change affecting the overall probability of obtaining positive health safety inspection certification. The degree of these is also in function of the potential value in price levels that a series of successful innovations has at any given dt .³⁶

Also in this subsystem a converter $HSProbRange_t$ defines the probability set by the stock $HSProb_t$ so it remains within the 0 to 100 range required by the Monte Carlo stochastic process $BioMCProb_t$ found in the *Development* module. The following logical function sets this range:

$HSProbRange_t$:

if $HSProb_t > 100$ **then**
 $HSProbRange_t \leftarrow 100$

³⁶Also here the levels of potential value displayed for $HealthSFund_t$ as well as the proportions by which $HSProbChage_t$ is multiplied within each converter, are those used later on to assess the behavior of both the model representing the cases of Mexico and that of Spain.

else

$$HSProbRange_t \leftarrow HSProb_t$$

The last segment within this module focuses on the system's infrastructure, describing how it fluctuates, captures investment, and allocates the existing research and development human capital over time. This mechanism points out the pivotal role that the public and private research centers mentioned by the multiple interviewed actors (like those ascribed to CONACyT, UNAM, and the National Polytechnic Institute-IPN in Mexico and those part of the National Research Council, CSIC, in Spain) have had in the development of this technology (see figure 3.12).

The two central stocks in this segment display the levels of existing infrastructure in each sector and are defined by the equations:

$$RInfra_t = \int_0^t (InRInfra_t - OutRInfra_t)dt + RInfra_{t-1} \quad (3.17)$$

and

$$DInfra_t = \int_0^t (InDInfra_t - OutDInfra_t)dt + DInfra_{t-1} \quad (3.18)$$

Where $RInfra_t$ is the level of existing research infrastructure measured in human capital levels; $InRInfra_t$ is the inflow of resources going to research infrastructure; $OutRInfra_t$ is the depletion level at which research infrastructure is used, depreciates, or becomes obsolete balancing the stock; and $RInfra_{t-1}$ is the available stock of research infrastructure available at $dt-1$. Conversely, $DInfra_t$ is the level of existing development infrastructure measured in human capital levels; $InDInfra_t$ is the inflow of resources flowing into development infrastructure; $OutDInfra_t$ is the depletion level at which development infrastructure is used, depreciates, or becomes obsolete balancing the stock; and $DInfra_{t-1}$ is the available stock of development infrastructure available at $dt - 1$.

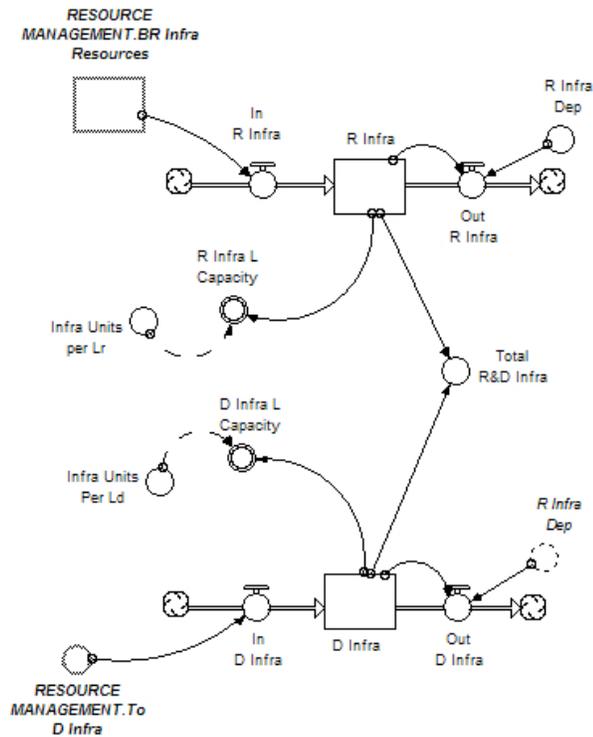


Figure 3.12: Infrastructure Mechanism

The variables $InRInfra_t$ and $OutRInfra_t$ as well as $InDInfra_t$ and $OutDInfra_t$ are a function of other variables as expressed by the following functions:

$$InRInfra_t = f(BRInfraResources_t)$$

$$OutRInfra_t = f(RInfraDep_t, RInfra_t)$$

and

$$InDInfra_t = f(ToDInfra_t)$$

$$OutDInfra_t = f(RInfraDep_t, DInfra_t)$$

Where $BRInfraResources_t$ is the stock of resources going to basic research from technology transfer activities and government funding (explained in more

detail within the *Resource Management* module); $RInfraDep_t$ is the depreciation rate of basic and applied research infrastructure; and $RInfra_t$ —as mentioned—is the available research infrastructure stock measured in human capital levels at dt ; $ToDInfra_t$ is the fraction of resources generated by development activities that are allocated for infrastructure; and $RInfraDep_t$ and $DInfra_t$ have been previously addressed.

The mathematical association between these variables is expressed by the equations:

$$InRInfra_t = BRInfraResources_t$$

$$OutRInfra_t = RInfraDep_t \cdot RInfra_t$$

$$InDInfra_t = ToDInfra_t$$

and

$$OutDInfra_t = RInfraDep_t \cdot DInfra_t$$

The actual infrastructure capacities measured in labor (human capital) are given within the $RInfraLCapacity_t$ and the $DInfraLCapacity_t$ converters, where:

$$RInfraLCapacity_t = \frac{RInfra_t}{InfraUnitsPerLr_t}$$

and

$$DInfraLCapacity_t = \frac{DInfra_t}{InfraUnitsPerLd_t}$$

define the actual number of individuals each sector can allocate at any given dt .

Finally, the converter $TotalR\&DInfra_t$ defines the sum of infrastructure available for both research and development within the system at any given time as:

$$TotalR\&DInfra_t = RInfra_t + DInfra_t$$

Resource Management

This module focuses on explaining the management of the essential inputs used in R&D processes like the accumulation and flow of human, financial, and natural resources. The behavior of exogenous variables associated to these —like population growth and the actual level of existing natural resources — is also considered. Further, the networks linked to the formation of new infrastructure and the variables affecting the degree and pace at which these cope with and incorporate labor hand into scientific and innovation activities is explored as well. The subsystems found in this module are allocated into six areas: 1) financial resources; 2) R&D savings and spending; 3) investment; 4) resources for infrastructure; 5) human capital; and 6) natural resources.

The financial resources area focuses on the net income accumulation going and flowing from three areas: a) research; b) development; and c) government. The first of these segments, addressing research, explains the levels of three stock through the following main equations:

$$TechTRtoD_t = \int_0^t (InTTfromD_t - OutTTfromD_t)dt + TechTRtoD_{t-1} \quad (3.19)$$

$$TechTRtoR_t = \int_0^t (InTTfromR_t - OutTTfromR_t)dt + TechTRtoR_{t-1} \quad (3.20)$$

and

$$NetFinRes_t = \int_0^t (InResR_t - OutNetFinR_t)dt + NetFinRes_{t-1} \quad (3.21)$$

Where for the first equation $TechTRtoD_t$ is the total stock of financial resources obtained by research as a sector from licensing new research (patented information) for development activities; $InTTfromD_t$ is the actual inflow of these resources coming from development as this sector pays for license usage;

$OutTTfromD_t$ is the balancing outflow of these resources going to either reinvestment in research activities, research infrastructure, or as taxes to the government (explained in detail later); and $TechTRtoD_t$ is the initial stock of financial resources obtained by the research sector from licensing new research for development activities. In the second equation $TechTRtoR_t$ represents the stock of financial resources obtained by research as a sector from licensing new research to other research activities; $InTTfromR_t$ is the inflow of resources coming from other research areas as these pay for the licensing fees; $OutTTfromD_t$ is the balancing outflow of these resources going to either reinvestment in research activities or research infrastructure. Since the benefits obtained from licensing back to research are considered as a redistributing research funding, these are considered tax exempt (this process is also explained in detail later); and $TechTRtoR_t$ is the initial stock of financial resources obtained from licensing back to research. In the final equation $NetFinRes_t$ is the total stock of financial resources going back to research either from licensing to development or back to research; $InResR_t$ is the inflow of these resources, coming as a fraction of both $OutTTfromD_t$ and $OutTTfromR_t$; the outflow of these resources considered as net income for research is given by $OutNetFinR_t$; and $NetFinRes_{t-1}$ is the initial stock of these resources (see figure 3.13).

Within the first main equation relative to resources coming from tech transfer to development, the level of $InTTfromD_t$ is given by the converter $FromLicensingD_t$ which ultimately defines the amount of financial resources coming from development into research every dt . The level of this variable is composed by the licensing rate plus the present value of the annual royalty charged from licensing. This value is then multiplied by $MktProb_t$, which represents the probability that innovations resulting from transferred knowledge

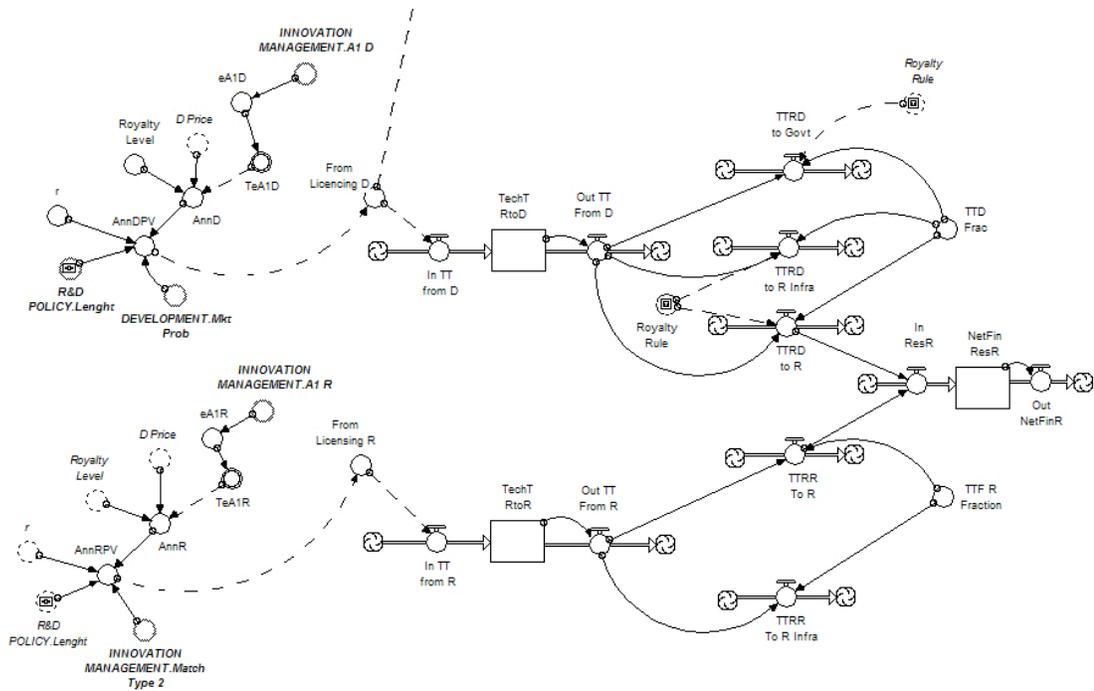


Figure 3.13: Financial Resources to Research

(A1) pass both biosafety and health inspection reviews (as explained in the previous *Development* segment). This last step assures that research collects royalties only when technology transfer produces innovations that reach the market. Further, since new knowledge (A1) is defined in “knowledge units” it has to be transformed (multiplied) by a demand Price $DPrice_t$ —set here at 100—before any financial valuation process is performed. It is assumed in the model that if new knowledge successfully becomes transformed into innovations and passes inspection, the market is willing to pay 100 times its original pre-transformation value. Thus, suggesting that the total market potential value of knowledge (A1) at any dt is one-hundred times that of its displayed untransformed level. Furthermore, since this market value is also given in terms of “knowledge units,” unit consistency is assured throughout the model. The process captured by this

converter is given by the equation:

$$AnnDPV_t = MktProb_t \cdot \left[AnnD_t \cdot \left(\frac{1 - ((1 + r_t)^{-Lenght_t})}{r_t} \right) \right]$$

Where $AnnDPV_t$ is total annual fee coming from tech transfer licensing to development, composed by the present value of the annual royalty charged for licensing multiplied by $MktProb_t$, which is the probability that the innovation passes both biosafety and health inspection; $AnnD_t$ is the initial licensing fee; r_t is the interest rate at which financial resources are discounted, set at 3%; and $Lenght_t$ represents the length of the patent as established by the IPR system within the *R&D Policy* module and is attached to a slider input device which allows changing its level at the model's interface.

The variable $AnnD_t$ plays a key role in this process by defining the amount of royalty as a fraction of the overall potential market value of transferred new knowledge (A1). This variable sets the equation:

$$AnnD_t = (TeA1D_t \cdot DPrice_t) \cdot RoyaltyLevel_t$$

Where $TeA1D_t$ is the last echelon of a series of converters that translate the level of transferred new knowledge (A1) from Ln into real numbers before it can undergo a series of mathematical operations; $DPrice_t$ is the per "knowledge unit" demand price; and $RoyaltyLevel_t$ is the fraction of transformed knowledge units that is charged as royalties for the use of new knowledge (A1), set at 4% of the total potential value of new knowledge (A1) at dt . As suggested, the level of $A1D_t$ is translated from Ln to natural numbers within a series of converters. The converter $eA1D_t$ begins the process through the following antilog transformation:

$$eA1D_t = e^{A1D_t}$$

Lastly, the converter $TeA1D_t$ sets a logical function that assures that when such transformation displays a value of 1, it becomes transformed into 0 (zero). This is due to the fact that when this transformation displays a level of 1 it is in fact capturing zero A1 production (an $A1D_t$ of 0) in the model at that particular dt . This function is:

$TeA1D_t$:

```

if  $eA1D_t = 1$  then
     $TeA1D_t \leftarrow 0$ 
else
     $TeA1D_t \leftarrow eA1D_t$ 

```

On the other end of this first main equation defining the total stock of financial resources obtained by research from licensing new research for development activities, the outflow $OutTTfromD_t$ —which is in function of $TechTRtoD_t$ — helps delimit three flows: $TTRtoGovt_t$, $TTRtoRIinfra_t$, and $TTRtoR_t$. These represent the fraction of this income going into the government as tax, to finance research infrastructure, or to fund further research, respectively. The level of each is defined by the converter $TTDFrac_t$, set at an even 33.33%. Affecting this particular allocation level is the converter $RoyaltyRule_t$ which represents whether or not a royalty rule is established, making the model emulate the royalty sharing rule set within Spain's *Real Decreto 55/2002* which establishes how the rights over inventions discovered within public research entities are designated and how capital returns emanating from these are distributed among these centers and the actual inventors. Again, this converter is controlled by a switch within the model's interface that either allows for this rule to be available or not. In particular, the behavior of each of the above mentioned flows is defined by a logical function which translates whether the pro-

portion of $OutTTfromD_t$ going into it is set by $TTDFrac_t$ or by $RoyaltyRule_t$.

The thread of functions is:

$TTRtoGovt_t$:

if $RoyaltyRule_t = 1$ **then**

$TTRtoGovt_t \leftarrow (OutTTfromD_t \times TTDFrac_t)$

else

$TTRtoGovt_t \leftarrow 0$

$TTRtoRInfra_t$:

if $RoyaltyRule_t = 1$ **then**

$TTRtoRInfra_t \leftarrow (OutTTfromD_t \times TTDFrac_t)$

else

$TTRtoRInfra_t \leftarrow (OutTTfromD_t \times 0.20)$

$TTRtoR_t$:

if $RoyaltyRule_t = 1$ **then**

$TTRtoR_t \leftarrow (OutTTfromD_t \times TTDFrac_t)$

else

$TTRtoR_t \leftarrow (OutTTfromD_t \times 0.80)$

Each of these flows become part of the total inflow of financial resources going to specific stocks (net financial resources to government and basic research resources for infrastructure, for the case of the first two). However, $TTRtoR_t$ is the only one that becomes a fraction of the inflow going to research's net stock of financial resources defined by $NetFinRes_t$.

Like in the first main equation, the flow $InTTfromR_t$ is given—in this case—by the converter $FromLicensingR_t$ which defines the amount of financial resources coming from research back to research every dt . In a similar way, the level of this variable is composed by the licensing rate plus the present value of the annual royalty charged from licensing. The value here is multiplied by

$MatchType2_t$, which, as explained in the *Development* module, represents the probability that newly produced knowledge is not allocated within the development sector and thus, becomes available for transfer back to research. The rest of the process is completely analogous to that followed by the pricing and valuation processes explained for new knowledge (A1) when it becomes transferred to development. The equation for the case of research royalty valuation is:

$$AnnRPV_t = MatchType2_t \cdot \left[AnnR_t \cdot \left(\frac{1 - ((1 + r_t)^{-Lenght_t})}{r_t} \right) \right]$$

Where $AnnRPV_t$ is total annual fee coming from tech transfer licensing to research, composed by the present value of the annual royalty charged for licensing multiplied by $MatchType2_t$, which is the probability that the innovation is allocated back to research activities; $AnnR_t$ is the initial licensing fee; r_t is the interest rate (3%); and $Lenght_t$ is the length of the patent as established by the IPR system and ultimately defined by the slider input device at the model's interface.

Again, the variable $AnnR_t$ defines the amount of royalty as a fraction of the overall potential market value of transferred new knowledge (A1) with equation:

$$AnnR_t = (TeA1R_t \cdot DPrice_t) \cdot RoyaltyLevel_t$$

Where $TeA1R_t$ is the last converter translating the level of transferred new knowledge (A1) from Ln into real numbers; $DPrice_t$ is the per knowledge unit demand price and, since it is set by the market, it is at the same level as that for A1 transferred to development; and $RoyaltyLevel_t$ is the fraction of transformed knowledge units that is charged as royalties (4% of A1's total potential value at dt). Here $eA1R_t$ begins the Ln -to-natural number process using the transforma-

tion:

$$eA1R_t = e^{A1R_t}$$

Finally, the converter $TeA1R_t$ also sets a logical function assuring that when such transformation encounters a value equal to 1 in Ln terms, it translates it to 0 in natural numbers. The function is:

$$\begin{aligned} &TeA1R_t: \\ &\quad \mathbf{if} \ eA1R_t = 1 \ \mathbf{then} \\ &\quad \quad TeA1R_t \leftarrow 0 \\ &\quad \mathbf{else} \\ &\quad \quad TeA1R_t \leftarrow eA1R_t \end{aligned}$$

In this case the outflow of this second main equation $OutTTfromR_t$ —here in function of $TechTRtoR_t$ —helps explain only two flows: $TTRtoRInfra_t$, and $TTRtoR_t$, to which resources coming from this stock go. As opposed to the outflow coming from the stock of resources produced from licensing to development, there is no percentage of this serving as taxes, due mainly to the assumption that most resources going into research activities originally stem from the various levels of government. The fraction going to each is defined by the converter $TTRfrac_t$, here set at 95%, suggesting that such percentage goes back to funding research activities and 5% of these resources are allocated to infrastructure. The functions defining the two flows are:

$$TTRtoR_t = OutTTfromR_t \cdot TTRfrac_t$$

and

$$TTRtoRInfra_t = [OutTTfromR_t \cdot (1 - TTRfrac_t)]$$

In the third of the above mentioned main equations, the income coming to research as a sector is the sum of the portions coming from both licensed to

research and that from licensing to development. The flow is defined by the expression:

$$InResR_t = TTRDtoR_t + TTRRtoR_t$$

While the outflow $OutNetFinR_t$, is in function of the total stock of financial resources $NetFinResR_t$ and defines the sector's total income that reaches the financial market as savings or various types of investment.

The segment explaining the amount of financial income going into development is defined by the stock of resources coming from capital gains deriving from new innovations reaching the market. Two stocks define this level: $TotalDRes_t$, which is the general amount of resources coming into development, and $NetFinResD_t$, which is the amount allocated for the sector's savings and spending. These stocks are defined by the equations:

$$TotalResD_t = \int_0^t (InTotalResD_t - OutTotalResD_t)dt + TotalResD_{t-1} \quad (3.22)$$

and

$$NetFinResD_t = \int_0^t (InNetFinD_t - OutNetFinD_t)dt + NetFinResD_{t-1} \quad (3.23)$$

Where in the first equation $InTotalResD_t$ is the incoming flow of resources to development as a sector; $OutTotalResD_t$ is the total outflow of these resources going to either the stock of net resources or to infrastructure investment; and $InTotalResD_{t-1}$ is the initial stock of these resources. In the second equation $InNetFinD_t$ is the inflow of total financial resources coming to development that is allocated to either savings or spending; $OutNetFinD_t$ is the balancing outflow of these that is either spent or saved; and $NetTotalResD_{t-1}$ is the initial level of net financial resources for development (see figure 3.14).

In particular, the inflow $InTotalResD_t$ displays the function:

$$InTotalResD_t = [PreTaxKd_t - (PreTaxKd_t \cdot TaxRate_t)]$$

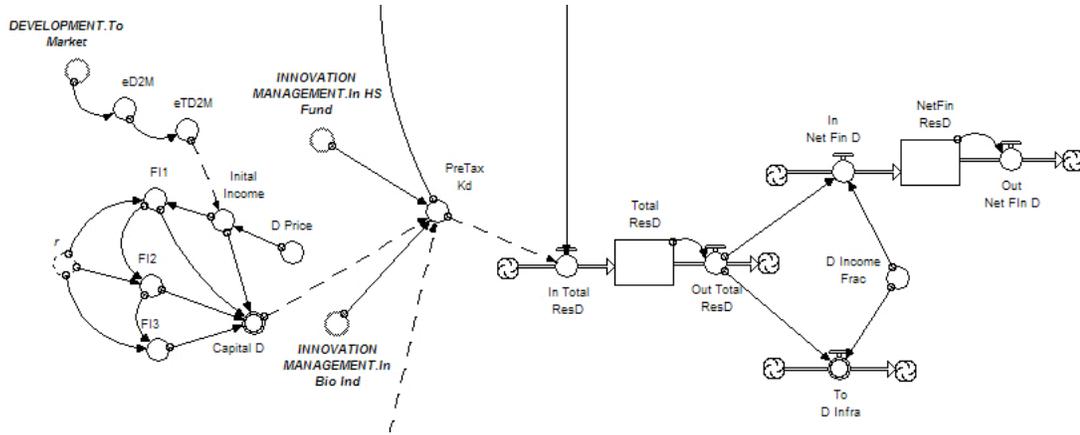


Figure 3.14: Financial Resources to Development

Where $PreTaxKd_t$ is the pre-tax amount of financial resources flowing into development as a sector and $TaxRate_t$ is the percentage of this income that goes to the government in the form of tax.

Here, $PreTaxKd_t$ serves as a conveyor which defines the pre-tax income for development from the total capital gains coming from innovation minus the expenses required for these to reach the market. The equation for this process is:

$$PreTaxKd_t = [((CapitalD_t - FromLicensingD_t) - InBioInd_t) - InHSFund_t]$$

Where both $InBioInd_t$ and $InHSFund_t$ are the levels of resources coming from development into biosafety and health inspection services, respectively, as defined in the *Innovation Management* module; $FromLicensingD_t$ defines the amount of financial resources coming from development into research every dt; and $CapitalD_t$ is the total “knowledge units” translated by market price coming to development from new innovations reaching the market.

The degree of $CapitalD_t$ flowing into development is defined by a process of valuation that depends on various variables including $ToMarket_t$, which ultimately defines the level of initial income $InitialIncome_t$; the interest rate r_t ; and

the market price $DPrice_t$. More specifically, $CapitalD_t$ is defined as:

$$CapitalD_t = InitialIncome_t + FI1_t + FI2_t + FI3_t$$

Where $InitialIncome_t$ is the last link of a chain of conveyors that translate the levels of $ToMarket_t$ from Ln to natural numbers and represents the rate of innovation produced at $dt - 1$ in market prices,³⁷ and $FI1_t$, $FI2_t$, and $FI3_t$ are a series of conveyors which define the present value of future financial flows coming to development from innovations reaching the market today.

The first of these two processes defines the degree of initial income by translating the levels of $ToMarket_t$. In this case $eD2M_t$ begins the Ln -to-natural number process using the transformation:

$$eD2M_t = e^{ToMarket_t}$$

Then, the converter $TeD2M_t$ also sets a logical function assuring that when such transformation encounters a value equal to 1 in Ln terms, it becomes translated to 0 in natural numbers. This function is:

$$\begin{aligned} &TeD2M_t: \\ &\quad \mathbf{if } eD2M_t = 1 \mathbf{ then} \\ &\quad \quad TeD2M_t \leftarrow 0 \\ &\quad \mathbf{else} \\ &\quad \quad TeD2M_t \leftarrow eD2M_t \end{aligned}$$

As suggested, the variable $InitialIncome_t$ itself is defined as the $ToMarket_t$ amount delayed by one period. This, in order to capture the fact that financial returns gained once an innovation reaches the market are felt by the sector a period later.

In the second process, the initial capital going to development represented by $InitialIncome_t$ is complemented by the expected capital flows produced by

³⁷In order to avoid a higher degree of complexity in the model, prices are assumed constant.

such market-reaching innovations in the following three complete periods, before their innovation's market value reaches zero. The previously mentioned conveyors define these values as:

$$FI1_t = 0.5 \cdot \frac{InitialIncome_t}{(1 + r_t)^1}$$

$$FI2_t = 0.25 \cdot \frac{FI1_t}{(1 + r_t)^2}$$

and

$$FI3_t = 0.1 \cdot \frac{FI2_t}{(1 + r)^3}$$

Basically, what these conveyors suggest is that the value of a bundle of innovations defined by $ToMarket_t$ at any given dt keep producing returns — although at a lesser level— at $dt + 1$, $dt + 2$, and $dt + 3$. This also concurs with both depreciation and obsolescence principles while also capturing the effects of “creative destruction.”

On the other hand, the decision of what proportion of output coming from the stock of total resources to development $OutTotalResD_t$ goes either to net financial resources or infrastructure is set by the conveyor $DIncomeFrac_t$. This parameter is defined at 80%, where 80% goes to net financial resources and 20% of becomes allocated to infrastructure. The functions defining these two flows are:

$$InNetFinD_t = OutTotalResD_t \cdot DIncomeFrac_t$$

and

$$ToDInfra_t = [OutTotalResD_t \cdot (1 - DIncomeFrac_t)]$$

Finally, for development income, the outflow $OutNetFinD_t$ is in function of the total stock of financial resources $NetFinResD_t$ and defines the sector's

total income that reaches the financial market as savings or various types of investment.

The third and last segment in the financial resources area focuses on the amount of these going into government from either research or development sectors. The stock here defined are the government's net financial resources $NetResGovt_t$; the level of resources going to research $GovtR_t$ and those going to development $GovtD_t$; and resources assigned to funding basic research infrastructure $GovtInfra_t$. These are defined by the equations:

$$NetResGovt_t = \int_0^t (InResGovt_t - OutResGovt_t)dt + NetResGovt_{t-1} \quad (3.24)$$

$$GovtR_t = \int_0^t (InGovtR_t - OutGovtR_t)dt + GovtR_{t-1} \quad (3.25)$$

$$GovtDFund_t = \int_0^t (InGovtD_t - OutGovtD_t)dt + GovtD_{t-1} \quad (3.26)$$

and

$$GovtInfra_t = \int_0^t (InGovtInfra_t - OutGovtInfra_t)dt + GovtInfra_{t-1} \quad (3.27)$$

Where $InResGovt_t$ in the first equation is the multiple source inflow going into the government's stock of available funding for biotech-related R&D activities; $OutResGovt_t$ is the outflow going from this stock to either research, development, or infrastructure for biotech R&D; and $NetResGovt_{t-1}$ is the initial stock of these resources. In the second equation, $InGovtR_t$ is the incoming fraction of net government resources for biotech research; $OutResGovt_t$ is the actual flow of resources used in the production of new knowledge (A1), part of the process described within the *Research* module; and $InGovtR_{t-1}$ is the initial stock of government resources going to these type of research activities. In the third equation, $InGovtD_t$ is the fraction of all government resources allotted to development; $OutGovtD_t$ gives the resource flow going to development activities also

as described within the *Development* module; and $InGovtD_{t-1}$ is the initial level of these at $dt - 1$. For the last equation, $InGovtInfra_t$ is the percentage of government resources used for basic research infrastructure; $OutGovtInfra_t$ is the total flow of resources going to funding and upgrading research infrastructure; and $InGovtInfra_{t-1}$ is this stock's initial level (see figure 3.15).

As mentioned, the degree of inflow to $InResGovt_t$ is composed by various outflows, other converter-defined parameters, and a switch, all which are either defined within this or other modules. Further, the level at which financial resources flow into government depends on a logical argument defined within this flow as:

$InResGovt_t$:

if $FixR\&DFundSwitch_t = 1$ **then**

$$InResGovt_t \leftarrow (FixGovtFund_t + [FiscalInD_t + TTRDtoGovt_t + BioIndtoGovt_t + OutRSavings_t + RiskFreeComp_t])$$

else

$$InResGovt_t \leftarrow FiscalInD_t + TTRDtoGovt_t + BioIndtoGovt_t + OutRSavings_t + RiskFreeComp_t$$

Where $FixR\&DFundSwitch_t$ represents the level (1 or 0) of a switch that controls within the model whether the government is allocating or not a fixed amount of funding for biotech R&D every dt ; $FixGovtFund_t$ is the fixed amount of resources the government allots (in case it does) to biotech R&D every dt (which happens in both Spain and Mexico); $FiscalInD_t$ is the amount of resources coming into government from taxes paid by development as a sector; $TTRDtoGovt_t$ is the proportion of resources going into government from licensing new knowledge (A1) to development when the "royalty rule" is switched on; $BioIndtoGovt_t$ is the outflow of resources coming to the government from the biosafety industry; and $OutRSavings_t$ and $RiskFreeComp_t$ is the amount

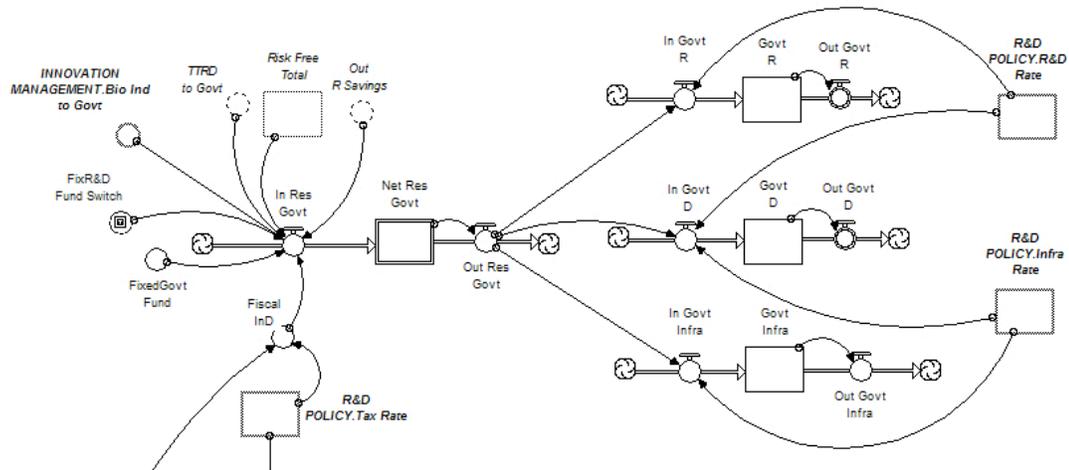


Figure 3.15: Financial Resources to Government

of resources looping back into the government from research through savings and investment in government papers.³⁸ Here, $FiscalInD_t$ is in function of $TaxRate_t$, variable set within the *R&D Policy* module, and $PreTaxKd_t$, explained in the previous segment, and is defined by the logical function:

$FiscalInD_t$:

if $PreTaxKd_t < 0$ **then**

$$FiscalInD_t \leftarrow 0$$

else

$$FiscalInD_t \leftarrow PreTaxKd_t \times TaxRate_t$$

The outflow of the first and central equation $OutResGovt_t$ is in function of the government's net stock of financial resources, $NetResGovt_t$, and eventually defines the proportion of the inflows $InGovtR_t$, $InGovtD_t$, and $InGovtInfra_t$, going into the stock of resources the government allocates for research, development, or R&D infrastructure, respectively. The actual level going from this central outflow to each of these inflows is given by two rates: $R\&DRate_t$ and

³⁸For these two levels it is assumed that research's savings as a sector and both research and development's total stock of risk-free investment is used to buy government risk-free bonds and bills, and that the government loops the resources gained from selling these back into the system via direct investment.

$InfraRate_t$, scales detailed within the *R&D Policy* module and initially set at 84% and 10% each. The functions for each of these flows are:

$$InGovtR_t = OutResGovt_t \cdot R\&DRate_t$$

$$InGovtD_t = OutResGovt_t \cdot [(1 - R\&DRate_t) - InfraRate_t]$$

and

$$InGovtInfra_t = OutResGovt_t \cdot InfraRate_t$$

Finally for this segment, all three outflows $OutGovtR_t$, $OutGovtD_t$, and $OutGovtInfra_t$ are in direct function of the available stock level for research, development, and infrastructure each dt .

The second area within this module explains the dynamics of each of the two central sectors within the model as these accommodate their earnings between savings and spendings. Here, the level of eleven stocks define how income is allocated into savings, spent in products and services outside the biotech R&D system, or used to ease venture capital investors' concerns about payback capacity (see figure 3.16). The two stock representing the behavior of research as a sector and are defined by the equations:

$$RIncome_t = \int_0^t (InRInc_t - OutRInc_t)dt + RIncome_{t-1} \quad (3.28)$$

and

$$VCRFund_t = \int_0^t (InVCRFund_t - OutVCRFund_t)dt + VCRFund_{t-1} \quad (3.29)$$

Where $RIncome_t$ is the total income going into research; $InRInc_t$ is the inflow of financial resources coming into this stock; the total resource outflow going either to spendings or savings is $OutRInc_t$; and $RIncome_{t-1}$ is the initial level

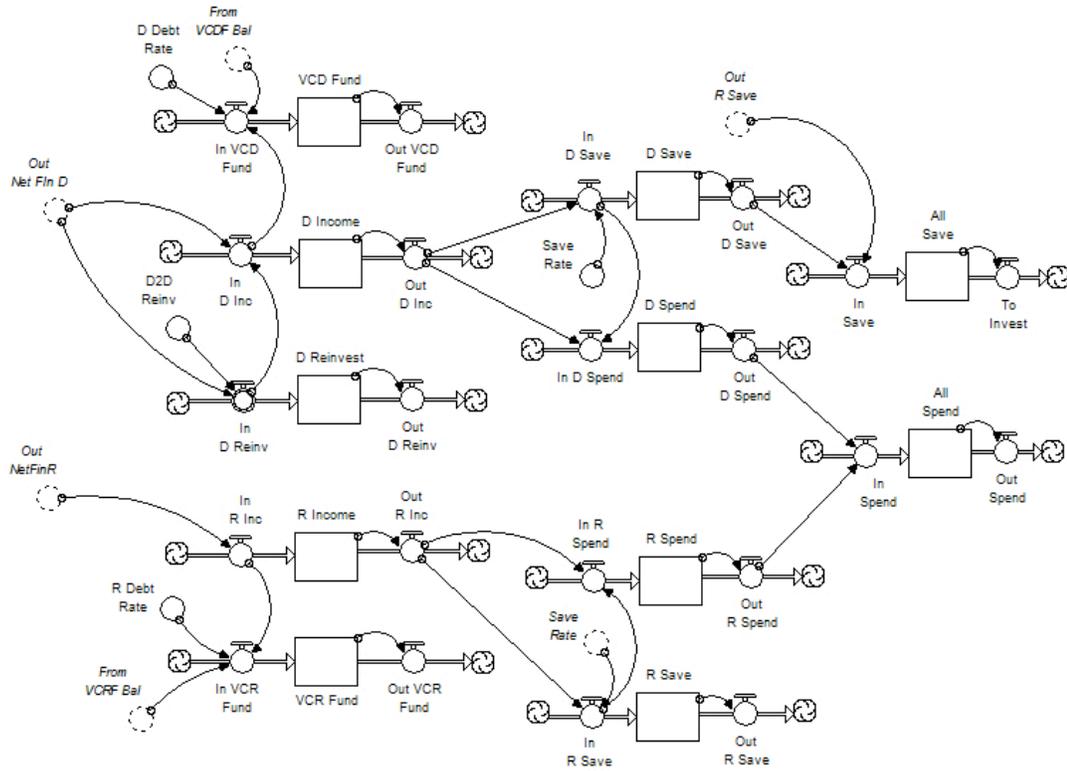


Figure 3.16: R&D Investment, Saving and Spending

of this stock. In the second equation, $VCRFund_t$ represents the stock of available funding necessary to back up any venture capital investment initiative in the sector; $InVCRFund_t$ is the actual level of these resources coming into the fund composed by the leftover balance generated once venture capitalists recover their investments, plus a nominal fraction of the available income coming into research every dt , which serves as proof for the sector's payback capacity.³⁹ This flow is defined by the interaction of two variables: $RDebtRate_t$, which sets the maximum level of income that can be allocated for debt pay-

³⁹Although a fraction of $InRInc_t$ is considered part of the resource inflow going to $VCRFund_t$, it is not discounted from this flow due to the fact that such fraction is only accounted for in this stock nominally to provide more arguments to support the sector's solvency. In fact, what this fraction represents is the maximum leverage capacity of the sector; in other words, the $DebtRate_t$ parameter defines the maximum level of income that can be allocated to debt paying and the fraction of income it represents is used in the venture capital subsystem later in this module as reference of the sector's payback ability.

ment, and $FromVCRFBal_t$ representing the inflow of leftover balance generated once venture capitalists recover their investments in knowledge production. $OutVCRFund_t$ is the balancing outflow for this stock; and $VCRFund_{t-1}$ is the fund's initial level.

In particular, the flow $InRInc_t$ is equal to $OutNetFinR_t$ while $OutRInc_t$ defines the levels of income flowing either into the sector's spending and savings. These are given depending on the parameter $SavingsRate_t$ set in the model at 25%. The equations for these two stock are defined as:

$$RSpend_t = \int_0^t (InRSpend_t - OutRSpend_t)dt + RSpend_{t-1} \quad (3.30)$$

and

$$RSave_t = \int_0^t (InRSave_t - OutRSave_t)dt + RSave_{t-1} \quad (3.31)$$

Where $RSpend_t$ is the stock of income going towards expenditures; $InRSpend_t$ is the fraction of total income that is allocated to spending (as mentioned 25% of the total); $OutRSpend_t$ is the balancing outflow of income used for spending that becomes part of the total stock of resources that eventually exit the system; and $RSpend_{t-1}$ is the initial stock of spendings. In the second equation, $RSave_t$ represents the stock of income going towards savings; $InRSave_t$ is the residual fraction of total income (75%) going to savings after discounting that going to spending; $OutRSave_t$ is the balancing outflow going into the general R&D savings stock; and $RSave_{t-1}$ is the initial level of these resources.

The behavior of development as a sector can be represented in quite an analogous way to that of research. Yet, this segment adds a third equation to those two previously explored introducing the possibility of further reinvestment in the sector. The sector's three equations are:

$$DIncome_t = \int_0^t (InDInc_t - OutDInc_t)dt + DIncome_{t-1} \quad (3.32)$$

$$VCDFund_t = \int_0^t (InVCDFund_t - OutVCDFund_t)dt + VCDFund_{t-1} \quad (3.33)$$

and

$$DReinvest_t = \int_0^t (InDReinv_t - OutDReinv_t)dt + DReinvest_{t-1} \quad (3.34)$$

Where the variables within the first and second equations behave practically the same way as those for research with a few variations; $DIncome_t$ is the total income going into development; $InDInc_t$ is the inflow of resources coming into the income stock; also here the total resource outflow going either to spendings or savings by the sector is $OutDInc_t$; and $DIncome_{t-1}$ is the stock's initial level. The second equation, $VCDFund_t$ displays the stock of available funding necessary to intice any venture capital initiative in the development; $InVCDFund_t$ is the level of these resources coming into such fund also composed by the left-over balance generated once venture capitalists recover their investments in development, plus a nominal fraction of the available income coming into development every dt . Again, this serves as proof for the sector's payback capacity. This flow is also defined by the interaction of two variables: $DDebtRate_t$, setting the limit to the amount of income that can be used for debt payment, and $FromVCDFBal_t$ displaying the inflow of leftover balance generated once venture capitalists recover their investments in innovation. $OutVCDFund_t$ is the balancing outflow for this stock; and $VCDFund_{t-1}$ is its initial level. In the third equation $DReinvest_t$ represents the stock of income that is reinvested into development; $InDReinv_t$ is the inflow of reinvestment as a percentage of the net financial resources going to development; $OutDReinv_t$ is the stock's balanc-

ing outflow; and $DReinvest_{t-1}$ is the initial stock of income being reinvested in development.

In this case, the flows $InDInc_t$ and $InDReinvest_t$ are fractions of $OutNetFinD_t$ defined by the conveyor $D2DReinv_t$, which defines the level of reinvestment at 15% and, consequently, that of the total income to development at 85%. On the other hand, $OutDInc_t$ defines the volume of income flowing either into the sector's spending and savings. These volumes are also given by the parameter $SavingsRate_t$ at 25% and 75%, respectively. The equations for these two stock are:

$$DSpend_t = \int_0^t (InDSpend_t - OutDSpend_t)dt + DSpend_{t-1} \quad (3.35)$$

and

$$DSave_t = \int_0^t (InDSave_t - OutDSave_t)dt + DSave_{t-1} \quad (3.36)$$

Where $DSpend_t$ is the stock of spent income; $InDSpend_t$ is the fraction of total income going to spending (25% of the total); $OutDSpend_t$ is the balancing outflow of income used for spending that goes into the total stock of income exiting the system; and $DSpend_{t-1}$ is the initial stock of spendings. For the second equation, $DSave_t$ is the stock of income going to savings; $InDSave_t$ is the residual fraction of total income (75%) going to savings; $OutDSave_t$ is the balancing outflow going into the total R&D savings stock; and $DSave_{t-1}$ is this stock's initial level.

The last two stocks defined in this segment capture the level of total savings and spending levels for both sectors. The equations for these are:

$$AllSave_t = \int_0^t (InSave_t - ToInvest_t)dt + AllSave_{t-1} \quad (3.37)$$

and

$$AllSpend_t = \int_0^t (InSpend_t - OutSpend_t)dt + AllSpend_{t-1} \quad (3.38)$$

Where $AllSave_t$ represents the total stock of savings for both research and development; $InSave_t$ is the flow of these resources coming into savings, composed by the sum of the flows $OutRSave_t$ and $OutDSave_t$; $ToInvest_t$ is the outflow of these resources flowing into the stock representing the various types of investment in the model; and $AllSave_{t-1}$ is the initial savings stock for both sectors. For the second equation $AllSpend_t$ is the total level of resources used in spending by both sectors, $InSpend_t$ is the inflow of income from going into spending, in this case composed by the sum of $OutRSpend_t$ and $OutDSpend_t$; $OutSpend_t$ is the flow of resources going out of the system as these are spent on products and services beyond the realm of the model; and $AllSpend_{t-1}$ is the initial stock of spendings.

The third area in this module explains how the segment of income devoted to investment is allocated into multiple options, ranging from outside R&D risk-free investments to biotech venture capital endeavors. This section is divided into three parts: a) the behavior of the core venture capital resource stock and the decision processes behind investment activities in either sector; b) the debt to earnings process for each sector engaged in venture capital; and c) the international venture capital process. This segment introduces in the model the notion that private investments flowing into modern biotech come mostly from corporate groups who put together specialized funds and then search for specific projects in which to invest these resources. It also addresses the fact that some venture funding is as well made available through funds set at various levels of government throughout the EU. This comes from the views offered by representatives of the EFB, who mentioned the importance of the multiple

venture capital funds available in Europe, such as those emanating from the EU Commission, *Genoma España*, the EFB itself, or other international private initiatives.

The first section of this area focuses on five central stocks describing the tangible levels of venture capital investment, while also delineating the decision process followed to allocate investment either on research, development, or both. Also as part of the investment decision making process, the levels of six stocks representing the solvency of each sector are addressed. The equations for the first five stocks are:

$$VCTotal_t = \int_0^t (ToVC_t - OutVC_t)dt + VCTotal_{t-1} \quad (3.39)$$

$$RiskFreeInv_t = \int_0^t (ToRF_t - ToComp_t)dt + RiskFreeInv_{t-1} \quad (3.40)$$

$$RiskFreeComp_t = \int_0^t (ToComp_t)dt + RiskFreeTotal_{t-1} \quad (3.41)$$

$$VCtoR_t = \int_0^t (InVCtoR_t - OutVCtoR_t)dt + VCtoR_{t-1} \quad (3.42)$$

and

$$VCtoD_t = \int_0^t (InVCtoD_t - OutVCtoD_t)dt + VCtoD_{t-1} \quad (3.43)$$

Where $VCTotal_t$ is the total stock of investment allotted to venture capital; $ToVC_t$ is the inflow of these resources coming from the $AllSave_t$ stock; $OutVC_t$ is the balancing outflow of resources going either to research or development (process explained later in detail); and $VCTotal_{t-1}$ is the initial level of this stock. In the second equation $VCtoR_t$ is the amount of venture capital resources going to research activities; $InVCtoR_t$ is the actual flow of these resources coming into the stock; $OutVCtoR_t$ is the balancing outflow streaming

later into the stock of debt; and $VCtoR_t$ is the initial level of these. Similarly, in the third equation $VCtoD_t$ is the amount of venture capital resources used in development activities; $InVCtoD_t$ is the inflow level coming into the stock from $AllSave_t$; $OutVCtoD_t$ is the balancing outflow coming from this stock and turning into debt; and $VCtoD_{t-1}$. The fourth and fifth equations are part of a single set of flows and stocks, where $RiskFreeInv_t$ is the stock of risk-free investment; $ToRF_t$ is the actual portion of $AllSave_t$ that goes into risk free investment; $ToComp_t$ is the flow going to the total stock of resources compounded by the investment rate; and $RiskFreeInv_{t-1}$ is the initial stock of risk free investments. In the last segment, $RiskFreeComp_t$ is stock of compounded risk-free resources; and $RiskFreeTotal_{t-1}$ is the initial stock of these (see figure 3.17).

Within the first three equations, the degree of inflow $ToVC_t$ is set by the conveyor $VCInvest_t$; the level of this conveyor is given by the proportion $VC\%_t$ defined jointly by a logical function, the outflows of venture capital going to research and to development ($OutVCtoR_t$ and $OutVCtoD_t$, respectively), and a range of change set by $VCCChange_t$. Consequently, this mechanism also helps to define the level of resources flowing into risk-free investment $ToRiskFree_t$. This process introduces in the model another aspect of the “match-making” process that assists matching projects in need of resources with available funding, mentioned by multiple interviewed actors from Spain.

The function defining $VCInvest_t$ and the logical function for $VC\%_t$ are:

$$VCInvest_t = VC\%_t$$

and

$$VC\%_t:$$

if $OutVCtoR_t > 0$ or $OutVCtoD_t > 0$ then

$$VC\%_t \leftarrow (VC\%_t + 0.01)$$

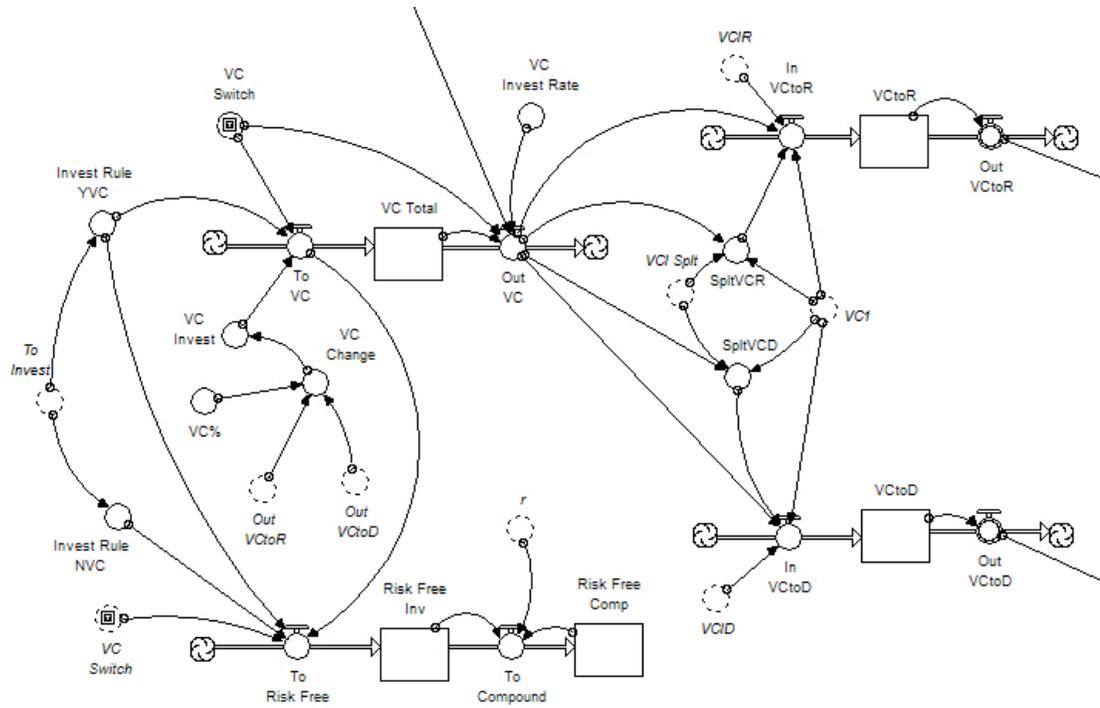


Figure 3.17: Risk-Free Investment and Venture Capital to R&D

else

$$VC\%_t \leftarrow (VC\%_t - 0.01)$$

In addition to this mechanism, the flows going into the stock of venture capital and risk-free investment depend on the levels of the switch $VCSwitch_t$, which suggests the presence (when displaying a level of 1) or absence (a level of 0) of venture capital investment in the model. The last two elements helping set the logical functions defining these inflows are $InvestRuleYVC_t$ and $InvestRuleNVC_t$. These —although both being technically equal to $ToInvest_t$, are necessarily different for the model to be able to differentiate the degree of these flows when venture capital investment is either present or not in the model. The logical functions for each of these inflows are:

$ToVC_t$:

if $VCSwitch_t = 1$ then

$$ToVC_t \leftarrow (InvestRuleYVC_t \times VCInvest_t)$$

else

$$ToVC_t \leftarrow 0$$

and

ToRiskFree_t:

if *VCSwith_{c_t}* = 1 **then**

$$ToRiskFree_t \leftarrow (InvestRuleYVC_t - ToVC_t)$$

else

$$ToRiskFree_t \leftarrow InvestRuleNVC_t$$

Conversely for these first three equations, the outflows *ToComp_t* and *OutVC_t* are also defined by multiple variables; the former is defined by the interest rate used throughout the model *r_t*, the stock of risk-free investment *RiskFreeInv_t*, and the compound stock of risk free investment *RiskFreeComp_t*. Since this last stock has no outflow, its balance becomes compounded by the interest rate every *dt* and such increment is added to the inflow of resources defined by *ToComp_t*. The function for this process is:

$$ToComp_t = [RiskFreeInv_t + (RiskFreeComp_t \cdot r_t)]$$

The latter, on the other hand, has a more complex composition; the total venture capital stock *TotalVC_t*, the conveyor *VCInvestRate_t*, which sets the percentage of the total available venture capital stock that gets invested every *dt* at 25%, the function *VC1_t* which defines an investment decision-making process to select which sector is more viable for venture capital investment each *dt*, and the *VCSwitch_t*, all partake in its definition. Further, the level for this flow is defined by the logical function:

OutVC_t:

if (*VC1_t* = 4 **or** *VC1_t* = 3 **or** *VC1_t* = 2) **and** *VCSwith_{c_t}* = 1
then

$$OutVC_t \leftarrow (VCTotal_t \times VCInvestRate_t)$$

else

$$OutVC_t \leftarrow 0$$

The conveyor $VC1_t$ is the last echelon of a chain of decision-making functions that ultimately define how and where the model—if it does—allocates venture capital. In this process, the net resources going to research and development, $NetFinResR_t$ and $NetFinResD_t$; the levels of capital going to either research or development, Kr_t and Kd_t with a delay equal to $dt - 1$ (each defined within their respective module); and the interest rate r_t , partake in this process. Two central conveyors— VCR_t and VCD_t —introduce the logical functions behind the decision-making rules $VC1_t$, $VC2_t$, $VC3_t$, and $VC4_t$, pivotal in this process. More specifically, the functions these conveyors define are:

VCR_t :

if $NetFinResR_t > (Kr_{t-1} \times r_t)$ **then**

$$VCR_t \leftarrow 1$$

else

$$VCR_t \leftarrow 0$$

and

VCD_t :

if $NetFinResD_t > (Kd_{t-1} \times r_t)$ **then**

$$VCD_t \leftarrow 1$$

else

$$VCD_t \leftarrow 0$$

What these logical functions suggest is that venture capital investors will risk their resources in either research or development only if the return on investment (ROI) levels displayed by either sector after one dt are above those these would have obtained if their resources were invested in risk-free options.

In other words, if the process provides sufficient information to verify that the rate of return (ROR) generated by either sector is indeed above r_t , venture capital becomes an option. This captures the views expressed by representatives of the EFB and the local bio-pharma industry in Spain regarding venture capital investment decision making. In the words of a representative of the EFB “companies taking too long to consolidate or not engaging in mergers with other start-ups at the precise time often appear unattractive for venture capital investors.” Stated differently, in the model only the sector that presents results in the short term has access to these resources.

The set of decision rules given by the conveyors $VC1_t$ to $VC4_t$ eventually helps decide whether research or development meet the requirement sought by venture capital investors. Depending on the levels of VCR_t and VCD_t these define if these resources go to either, both, or none of these sectors. The chain of logical functions for these converters is:

$VC1_t$:

if $VCR_t = 1$ and $VCD_t = 1$ then

$VC1_t \leftarrow 4$

else

$VC1_t \leftarrow VC2_t$

$VC2_t$:

if $VCR_t = 0$ and $VCD_t = 1$ then

$VC2_t \leftarrow 3$

else

$VC2_t \leftarrow VC3_t$

$VC3_t$:

if $VCR_t = 1$ and $VCD_t = 0$ then

$VC3_t \leftarrow 2$

else

$$VC3_t \leftarrow VC4_t$$

and

$VC4_t$:

if $VCR_t = 0$ **and** $VCD_t = 0$ **then**

$$VC4_t \leftarrow 1$$

else

$$VC4_t \leftarrow 0$$

These logical functions define which is the best option for allocating venture capital investment by number into the four possible scenarios: when both sectors are viable $VC1_t$ gets a level of 4; if development is the only viable option $VC1_t$ is 3; when research is the viable option $VC1_t$ is 2; and when none of the two are viable $VC1_t$ displays a level of 1. These are also essential within yet another decision process defining the actual venture capital flow going into research and development described in the last two equations dealt with in this section (see figure 3.18).

In addition to $OutVC_t$ and $VC1_t$, the inflows $InVCtoR$ and $InVCtoD_t$ going to the stock of venture capital of either research or development, respectively, are also in function of a series of conveyors; three of these, $VCIR_t$, $VCID_t$, and $VCISplit_t$, assist setting the level of international venture capital going to each sector when available in the model, while the last two, $SplitVCR_t$ and $SplitVCD_t$, define the logical functions that help allocate these resources (including international venture capital) depending on the viability defined by $VC1_t$ and the availability of international venture capital funding. The logical functions defining the two main inflows are:

$InVCtoR_t$:

if $VC1_t = 2$ **then**

$$InVCtoR_t \leftarrow (OutVC_t) + VCIR_t]$$

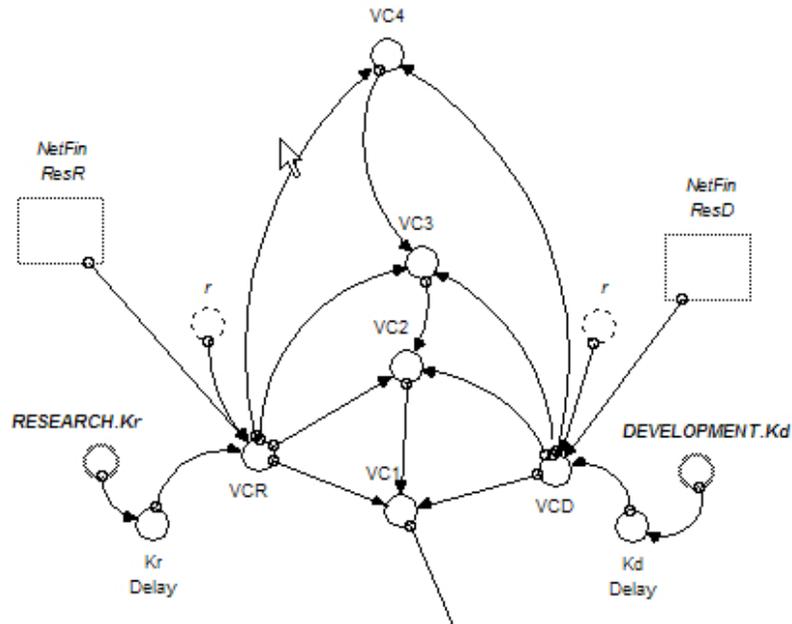


Figure 3.18: Venture Capital Investment Decision Mechanism

else

$$InVCtoR_t \leftarrow SplitVCR_t$$

and

$InVCtoD_t$:

if $VC1_t = 3$ **then**

$$InVCtoD_t \leftarrow VCI1_t$$

else

$$InVCtoD_t \leftarrow SplitVCD_t$$

The logical functions for the three conveyors assisting with international venture capital allocation are:

$VCIR_t$:

if $IntlVCSwitch_t = 1$ **then**

$$VCIR_t \leftarrow VCI3_t$$

else

$$VCIR_t \leftarrow 0$$

$VCID_t$:

if $IntlVCSwitch_t = 1$ **then**

$VCID_t \leftarrow VCI2_t$

else

$VCID_t \leftarrow 0$

and

$VCISplit_t$:

if $IntlVCSwitch_t = 1$ **then**

$VCISplit_t \leftarrow VCI1_t$

else

$VCISplit_t \leftarrow 0$

And, the functions for the two conveyors helping allocate venture capital resources based on the viability of these sectors are:

$SplitVCR_t$:

if not $(VC1 = 2)$ **and** $VC1_t = 4$ **then**

$SplitVCR_t \leftarrow [(0.5 \times OutVC_t) + VCISplit_t]$

else

$SplitVCR_t \leftarrow 0$

and

$SplitVCD_t$:

if not $(VC1 = 3)$ **and** $VC1_t = 4$ **then**

$SplitVCD_t \leftarrow [(0.5 \times OutVC_t) + VCISplit_t]$

else

$SplitVCD_t \leftarrow 0$

The conveyor $VCISplit_t$ is in function of the chance that international venture capital is available in the model. This is defined by the conveyor

$IntlVCSwitch_t$ using a 0 (off) or 1 (on) process controlled at the model's interface level. The variable $VCI1_t$ is the last conveyor in a series within a mechanism that assigns venture capital resources to either sector also depending on the $VC1_t$ levels.

Lastly, the outflows coming from research and development's venture capital stocks, $OutVCtoR_t$ and $OutVCtoD_t$, are equal to the levels of these stocks every dt . Furthermore, these are part of the inputs within the total capital (Kr_t and Kd_t) going to either sector as defined within the *Research* and *Development* modules, respectively. Moreover, these define the inflows going to the stock of debt resulting from the use of venture capital.

The second section in this area deals with the venture capital debt-to-earnings valuation for both research and development sectors and explains how the level of these flows influence the investors' overall decision-making process in the model. At the center of this process are a total of six stocks representing the degree of debt and funding that each sector has either incurred on or produced, respectively, from engaging in venture capital endeavors. Here, the stock of debt acquired by each sector — $VCtoRDebt_t$ and $VCtoDDebt_t$ — is defined and contrasted with the levels of the previously described resources backing venture capital, $VCRFund_t$ and $VCDFund_t$, analyzed in this module's area dedicated to savings and spending. The outcome of these differences provide each sector either a higher probability of gaining access to venture capital funding —due to the chance of displaying higher solvency to pay returns on investment as these accumulate over time— or a negative note, if the level of these cannot cover a marginal gain spread beyond that offered by risk-free investment.

The two flows describing the debt stock for each sector are represented by

the equations:

$$VCtoRDebt_t = \int_0^t (InVCRDebt_t - OutVCRDebt_t)dt + VCtoRDebt_{t-1} \quad (3.44)$$

and

$$VCtoDDebt_t = \int_0^t (InVCDDebt_t - OutVCDDebt_t)dt + VCtoDDebt_{t-1} \quad (3.45)$$

Where $VCtoRDebt_t$ is the total stock of venture capital invested in research expressed in debt terms; $InVCRDebt_t$ is the inflow of venture capital invested in research expressed in debt terms; $OutVCRDebt_t$ is the balancing outflow keeping this stock from accumulating; and $VCtoRDebt_{t-1}$ is the stock initial level. For the second equation, $VCtoDDebt_t$ is the total stock of venture capital going to development; $InVCDDebt_t$ is the inflow of venture capital invested in development in debt terms, following an analogous process to that of its research counterpart; $OutVCDDebt_t$ is the stock's balancing outflow; and $VCtoDDebt_{t-1}$ is the development's debt stock initial level (see figure 3.19).

In particular, the inflows $InVCtoRDebt_t$ and $InVCDDebt_t$ define the sum of total inflow and are represented by the equations:

$$VCtoRDebt_t = OutVCtoR_t + FromVCRDBal_t$$

and

$$VCtoDDebt_t = OutVCtoD_t + FromVCDDBal_t$$

Where $OutVCtoR_t$ and $OutVCtoD_t$ are the previously explained total stock of venture capital flows going into research and development, respectively, every dt ; $FromVCRDBal_t$ and $FromVCDDBal_t$ respectively represent the inflows going to each sector's stock of debt from venture capital.

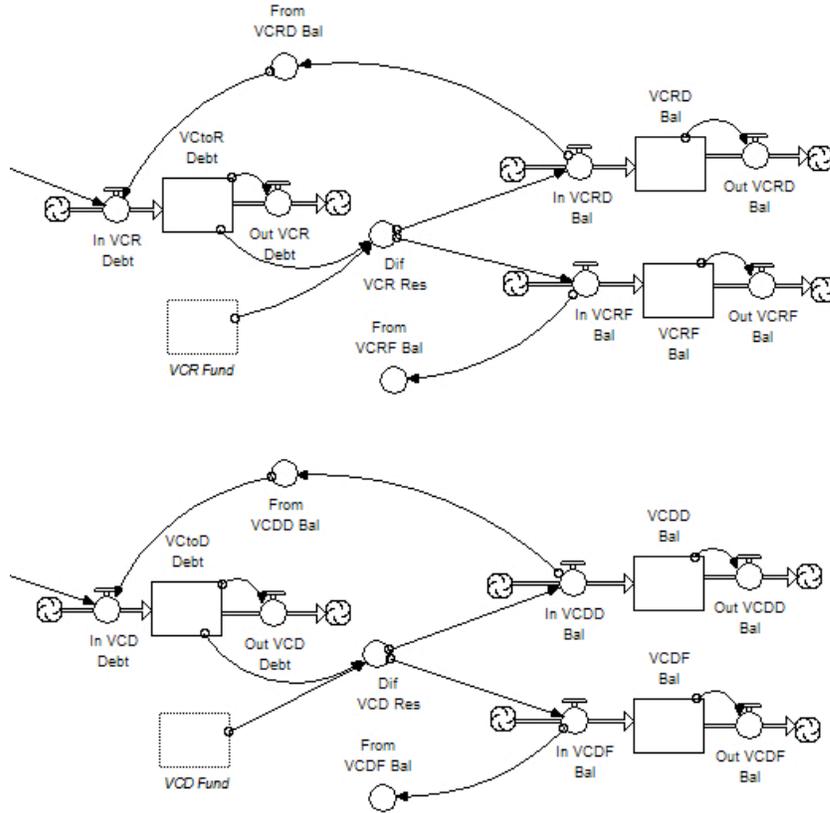


Figure 3.19: Venture Capital Funds and Debt Balance Stock

The actual difference between the levels of debt and earnings in either sector are given by the conveyors $DifVCRRes_t$ and $DifVCDRes_t$ through the equations:

$$DifVCRRes_t = VCRFund_t - VCtoRDebt_t$$

and

$$DifVCDRes_t = VCDFund_t - VCtoDDebt_t$$

The resulting products of these last two equations define the degree of resources flowing into the last four stocks dealt in this section, which describe the debt and earnings associated to venture capital as a stock for each of the two sectors. These also provide the level of the above described conveyors

$FromVCRDBal_t$ and $FromVCDDBal_t$, essential also in the previously described savings and spendings segment of this module. The equations for the research sector are:

$$VCRDBal_t = \int_0^t (InVCRDBal_t - OutVCRDBal_t)dt + VCRDBal_{t-1} \quad (3.46)$$

$$VCRFBal_t = \int_0^t (InVCRFBal_t - OutVCRFBal_t)dt + VCRFBal_{t-1} \quad (3.47)$$

and those for development are:

$$VCDDBal_t = \int_0^t (InVCDDBal_t - OutVCDDBal_t)dt + VCDDBal_{t-1} \quad (3.48)$$

$$VCDFBal_t = \int_0^t (InVCDFBal_t - OutVCDFBal_t)dt + VCDFBal_{t-1} \quad (3.49)$$

Where $VCRDBal_t$ represents the balance of the debt incurred by research derived from venture capital being allocated in the sector in the form of a stock; $InVCRDBal_t$ is the inflow of debt coming into the stock stemming from a negative difference between $VCRFund_t$ and $VCtoRDebt_t$ (the level of this inflow also defines that of $FromVCRDBal_t$); $OutVCRDBal_t$ is the balancing outflow; and $VCRDBal_{t-1}$ is the initial debts balance stock. In the second equation for research $VCRFBal_t$ is the balance of funding generated by the sector from venture capital investment; $InVCRFBal_t$ is the inflow of resources coming into the stock, in this case stemming from a positive difference between $VCRFund_t$ and $VCtoRDebt_t$ (the level of this inflow defines that of $FromVCRFBal_t$); $OutVCRFBal_t$ is the balancing outflow; and $VCRFBal_{t-1}$ is the initial balance of the funds stock. The variables in the two equations for development are analogous to those of research therefore requiring no detailing.

The third and last part in this section centers its attention on explaining the international venture capital process within the model. This process supplements the overall venture capital mechanism by introducing a series of rules that mimic the behavior of the various international venture capital resources available within the EU to which Spain has access to. Although this mechanism has its own on/off switch at the interface level, it can only be introduced in the model when the model itself allows for venture capital. In other words, when the overall venture capital switch at the interface level is on.

The process describes how international venture capital is allocated within the system partially relying on the outcome provided by the previously described venture capital investment decision mechanism. Just as the overall venture investment allocation, resources are made available either for research or development depending on both the returns on investment that these display and the total amount of “local” venture capital resources available within the model at dt . The central principle behind this process is that international funds such as those provided by continental agencies —like the European Federation of Biotechnology— or other private or public fund sources emanating from the EU government initiatives mentioned in the previous chapter, supplement the local venture initiatives by increasing the already allotted mounts of funding that the local investors provide.

There is only one central stock in this process describing the level of international investment resources as they become assigned between the two sectors. The equation for this stock is:

$$IntlVCFund_t = \int_0^t (InIntlVC_t - OutIntlVC_t)dt + IntlVCFund_{t-1} \quad (3.50)$$

Where $IntlVCFund_t$ is the total stock of international venture capital at dt ;

$InIntlVC_t$ is the flow of these resources coming into the stock; $OutIntlVC_t$ is the balancing outflow coming from the stock; and $IntlVCFund_{t-1}$ is the initial level of this stock (see figure 3.20).

In particular, the inflow $InIntlVC_t$ is equal to the international resources coming into the fund given by the converter $IntlVCInvest_t$, set at 100,000. What this flow tries to describe is the constant flow of resources that venture capital investors allocate to modern biotech as part of their international investment portfolios. The outflow, $OutIntlVC_t$, more than balancing the stock, actually determines the maximum amount of resources —as a percentage of the total available stock— can be allotted to either of the sectors. Two converters — $IntlVCInvestRate_t$ and $OutRestriction_t$ — and the total available stock of international venture capital help determine this level. From these conveyors, the former provides the percentage of the total stock available for international venture capital investment that can be invested every dt and is set at 10%; while the latter relies on the previously mentioned $VC1_t$ converter to define whether there will be venture capital investment or not each period. The logical function allowing this process set by this conveyor is:

$OutRestriction_t$:

if not ($VC1 = 2$ **or** $VC1_t = 3$ **or** $VC1_t = 4$) **then**

$OutRestriction_t \leftarrow 0$

else

$OutRestriction_t \leftarrow 1$

Ultimately, the equation for the outflow of venture capital injected into the system is given by:

$$OutIntlVC_t = (IntlVCFund_t \cdot IntlVCInvestRate_t) \cdot OutRestriction_t$$

Following this, two sets of converters help define which sector —if any— receives the resources given by this outflow. Again, the level expressed by the

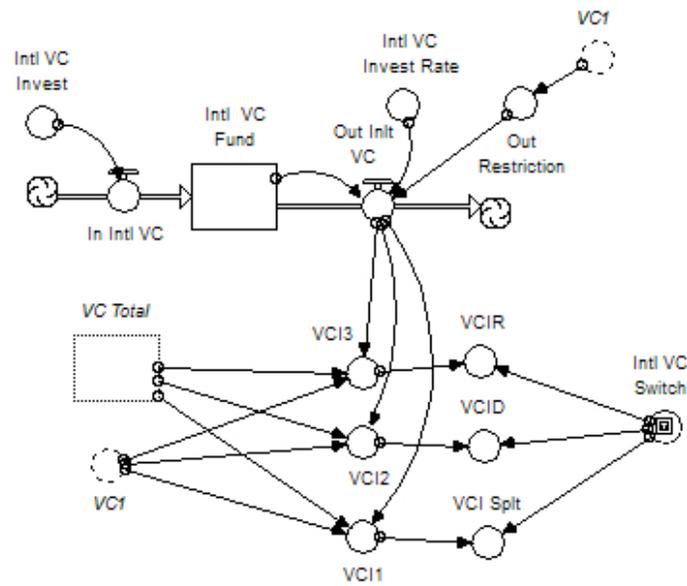


Figure 3.20: International Venture Capital Mechanism

conveyor $VC1_t$, along with the total stock of (local) venture capital, $VCTotal_t$, and the process' on or off switch, partake in this process. The first set of converters — $VCI1$, $VCI2$, and $VCI3$ — define what sector receives these resources and the logical functions for these are:

$VCI1_t$:

if $VCTotal_t < 10,000,000$ and $VC1 = 2$ then

$$VCI1_t \leftarrow OutIntlVC_t$$

else

$$VCI1_t \leftarrow 0$$

$VCI2_t$:

if $VCTotal_t < 10,000,000$ and $VC1_t = 3$ then

$$VCI2_t \leftarrow OutIntlVC_t$$

else

$$VCI2_t \leftarrow 0$$

and $VCI3_t$:

if $VCTotal_t < 10,000,000$ **and not** ($VC1 = 2$ **or** $VC1_t = 3$)
and $VC3_t = 4$ **then**

$$VCI1_t \leftarrow (0.5 \times OutIntlVC_t)$$

else

$$VCI3_t \leftarrow 0$$

Here, the conveyors $VCI1_t$ and $VCI2_t$ suggest that if the local venture capital funding available is less than ten million, international venture resources will be allocated to either research or development, respectively. The last converter $VCI3_t$ suggest that when both sectors appear viable for investment, the total available international funding should be split by these evenly.

The last set of converter operating in this part — $VCIR_t$, $VCID_t$, and $VCISplit_t$ — allow for the resource allocation previously defined to take place only when the international venture capital switch is turned on. The logical functions for each of these are:

$VCIR_t$:

if $IntlVCSwitch_t = 1$ **then**

$$VCIR_t \leftarrow VCI1_t$$

else

$$VCIR_t \leftarrow 0$$

$VCID_t$:

if $IntlVCSwitch_t = 1$ **then**

$$VCID_t \leftarrow VCI2_t$$

else

$$VCID_t \leftarrow 0$$

and

$VCISplit_t$:

if $IntlVCSwitch_t = 1$ **then**

$$VCISplit_t \leftarrow VCI3_t$$

else

$$VCISplit_t \leftarrow 0$$

The fourth area in this module explains the dynamics behind the accumulation of resources used for creating or updating basic research infrastructure. A single stock, capturing the multiple inflows going to the research sector defines the level of these (see figure 3.21). The equation representing the stock of these resources is:

$$BRInfraRes_t = \int_0^t (InBRInfra_t - OutBrInfra_t) dt + BRInfraRes_{t-1} \quad (3.51)$$

Where $BRInfraRes_t$ is the total available stock of resources for basic research infrastructure; $InBRInfra_t$ is the inflow of these coming into the stock; $OutBRInfra_t$ is the balancing outflow of these resources; and $BRInfraRes_{t-1}$ is the initial stock of these.

Here, the inflow $InBRInfra_t$ is composed by the sum of three variables defined by the conveyors $TTRDtoRInfra_t$, $TTRRtoRInfra_t$, and $OutGovtInfra_t$ previously explained in the financial resources area of this module. Each of these inflows stems either from technology transfer to development or research or from the government. On the other hand, $OutBRInfra_t$ is defined by the total level of stock each dt .

The fifth area in this module provides account of the stock of human capital resources in the model. This process explains how these shape into new biotech labor hand as well as the mobility these have between research and development activities when there is limited projection in either. As mentioned in previous sections, labor hand is expressed in terms of both individuals and the system's capacity to provide them with the environment where these can

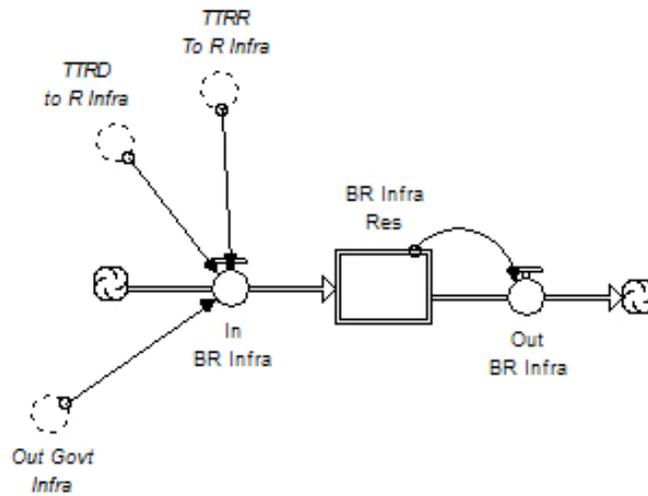


Figure 3.21: Resources for Basic Research Infrastructure

engage in either research or development activities (measured by the infrastructure resources available).

The first segment focuses on five stocks, including the overall labor hand in biotech and those for each of the two sectors, to detail the process by which human resources become available within the model. The first equation in this process is:

$$BiotechLabor_t = \int_0^t (InBioLab_t - OutBioLab_t)dt + BiotechLabor_{t-1} \quad (3.52)$$

Where $BiotechLabor_t$ is the total stock of labor hand in biotech; $InBioLab_t$ is the inflow of labor hand going into biotech; $OutBioLab_t$ is the balancing outflow of these; and $BiotechLabor_{t-1}$ is the initial level of this stock⁴⁰ (see figure 3.22).

⁴⁰It is important to mention that what both the inflow going and the outflow coming from the stock $BiotechLabor_t$ help define in the model is how the number of individuals wanting to become part of the biotech sector varies per period (i.e. how the number of students enrolling in biotech related degrees changes every dt). As in all areas of study, the level of students varies each period, therefore the need for these flows. The actual labor hand in research or development—as represented by the number of students enrolled in new biotech degrees leading towards these areas—is defined each period later in this process also using the level of the stock $BiotechLabor_t$ to do so.

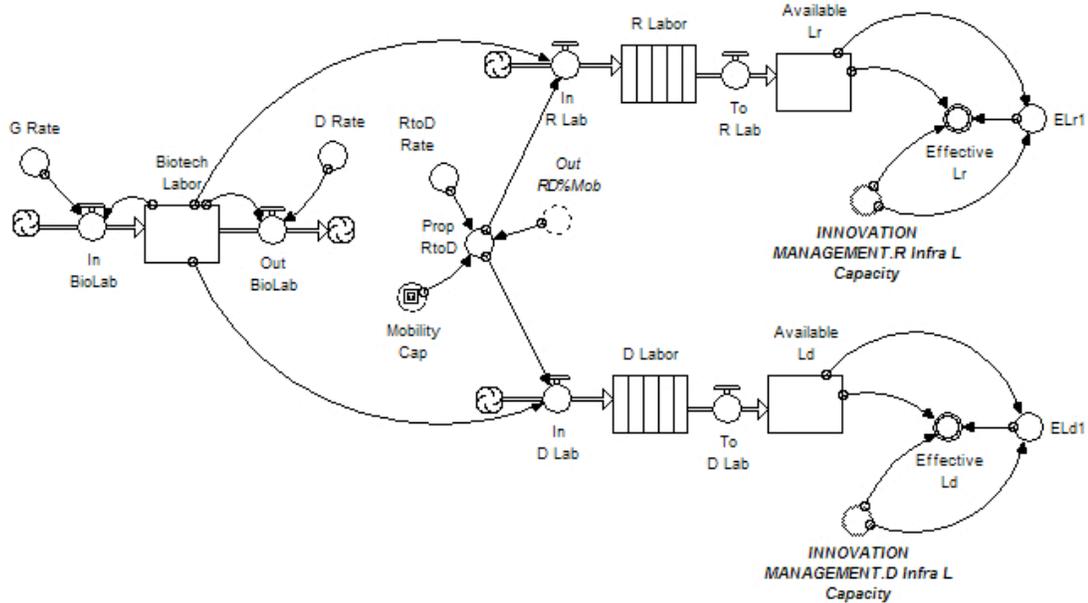


Figure 3.22: Available Human Capital for Biotech R&D

In particular, $InBioLab_t$ is an inflow equal to 2% of the total stock every dt as defined by the conveyor $GRate$. The equation for this flow is:

$$InBioLab_t = BiotechLabor_t \cdot GRate_t$$

On the other hand, the outflow $OutBioLab_t$, which displays a level equal to 0.01987% of the total stock of labor hand every dt , is defined by the conveyor $DRate_t$. The level of this outflow is give by the equation:

$$OutBioLab_t = BiotechLabor_t \cdot DRate_t$$

The difference between these flows —although quite small— suggests that in the model labor going into biotech is increasing over time.

The next segment explains the stock of labor hand pursuing either research or development tracks as well as the total available for each sector every dt . Since human capital formation in these areas demands time, the stock for these is initially represented in the model as a conveyor which preserves its inflow

for the time necessary for it to fully mature and thus, enter the stock of available labor hand. The equations for these stock are:

$$RLabor_t = \int_0^t (InRLab_t - ToRLab_t)dt + RLabor_{t-1} \quad (3.53)$$

$$AvailableLr_t = \int_0^t ToRLab_t \cdot dt + AvailableLr_{t-1} \quad (3.54)$$

$$DLabor_t = \int_0^t (InDLab_t - ToDLab_t)dt + DLabor_{t-1} \quad (3.55)$$

and

$$AvailableLd_t = \int_0^t ToDLab_t \cdot dt + AvailableLd_{t-1} \quad (3.56)$$

Where $RLabor_t$ is the stock operating as a conveyor keeping the portion of labor hand pursuing a research track for the average time it takes to fully develop human capital; $InRLab_t$ is the inflow coming into this conveyor from the total stock of biotech labor hand; $ToRLab_t$ is the outflow of fully developed human capital going into the stock of available labor hand for research; and $RLabor_{t-1}$ is the initial level of labor within this conveyor. For the second equation, $AvailableLr_t$ is stock of fully developed human capital in research; and $AvailableLr_{t-1}$ is the initial level of stock. The last two equations behave in quite an analogous way and thus, need not further detailing.

The levels of $InRLab_t$ and $InDLab_t$ are defined by a decision-making process which prescribes whether these are fixed —given by $RtoDRate_t$, set at 85% for research— or are variable and, therefore, in function of the mobility proportion between sectors, given by $OutRD\%Mob_t$ and ultimately defined by the conveyor $PropRtoD_t$. Assigning which of these processes is used is the switch $MobilityCap_t$ which, through a binary mechanism controlled at the model's interface (1 for “on” and 0 for “off”), suggests the presence of inter-sector mobility.

This process is introduced in the model to capture the effects of labor mobility within the EU.

To define whether mobility is available, the conveyor $PropRtoD_t$ attends to the following logical function:

$PropRtoD_t$:

```

if  $MobilityCap_t = 1$  then
     $PropRtoD_t \leftarrow OutRD\%Mob_t$ 
else
     $PropRtoD_t \leftarrow RtoDRate_t$ 

```

Lastly for this initial segment, the stock $AvailableLr_t$ and $AvailableLd_t$ also partake in a series of logical functions that help define the effective labor hand levels for each sector. These levels — $EffectiveLr_t$ and $EffectiveLd_t$ — ultimately establish the occupied labor hand within the respective existing research and development infrastructure. The process also involves the infrastructure capacities measured in labor (human capital) as given by $RInfraLCapacity_t$ and $DInfraLCapacity_t$. These last two parameters provide the actual number of individuals that each sector can allocate at any given dt , as previously explained in the *Innovation Management* module. Two final converters — $ELr1_t$ and $ELd1_t$ — set each sector's labor hand limit to that of their respective infrastructure capacity.

The logical functions set by the converters $EffectiveLr_t$ and $EffectiveLd_t$ are:

$EffectiveLr_t$:

```

if  $RInfraLCapacity_t \geq AvailableLr_t$  then
     $EffectiveLr_t \leftarrow AvailableLr_t$ 
else
     $EffectiveLr_t \leftarrow ELr1_t$ 

```

and

EffectiveLd_t:

if *DInfraLCapacity_t* \geq *AvailableLd_t* **then**

EffectiveLd_t \leftarrow *AvailableLd_t*

else

EffectiveLd_t \leftarrow *ELd1_t*

The last two converters, suggesting that each sector cannot accommodate more labor hand than its respective infrastructure can manage every *dt*, display the logical functions:

ELr1_t:

if *RInfraLCapacity_t* $<$ *AvailableLr_t* **then**

ELr1_t \leftarrow *RInfraLCapacity_t*

else

ELr1_t \leftarrow 0

and

ELd1_t:

if *DInfraLCapacity_t* $<$ *AvailableLd_t* **then**

ELd1_t \leftarrow *DInfraLCapacity_t*

else

ELd1_t \leftarrow 0

The second segment in this area defines how the stock that captures the percentage of inter-sector labor hand mobility changes when the infrastructure's capacity is not sufficient to accommodate the flow of labor hand coming from the conveyors *RLabor_t* and *DLabor_t*. This process sets off a decision-making process involving the stock of available labor hand for research *AvailableLr_t*; the parameter *RInfraLCapacity_t* providing the actual number of individuals that research as a sector can allocate at any given *dt*; and a series of converters

defining the proportion of change that each of the possible scenarios can produce on the stock $RtoD\%Mobility_t$. The equation for this stock is:

$$RtoD\%Mob_t = \int_0^t (InRtoD\%Mob_t - OutRtoD\%Mob_t)dt + RtoD\%Mob_{t-1} \quad (3.57)$$

Where $RtoD\%Mob_t$ is the the level of research-to-development intra-sector mobility represented as a stock; $InRtoD\%Mob$ is the inflow to this stock, composed by the sum of the stock's $dt - 1$ level plus the percentage of change estimated by the decision-making mechanism defined in this process given by $RtoDArbit_t$; $OutRtoD\%Mob$ is the balancing outflow equal to the level of the stock each dt ; and $RtoD\%Mob_{t-1}$ is the initial level of this stock (see figure 3.23).

The converter $RtoDArbit_t$, along with three additional converters — $RtoD1_t$, $RtoD2_t$, and $Change\%LR_t$ — ultimately defines if the newly formed research human capital needs to move to development because research offers no appointment. The logical functions for these converters are:

$RtoDArbit_t$:

if $AvailableLr_t = RInfraLCapacity_t$ **then**

$RtoDArbit_t \leftarrow 0$

else

$RtoDArbit_t \leftarrow RtoD1_t$

$RtoD1_t$:

if $AvailableLr_t > RInfraLCapacity_t$ **then**

$RtoD1_t \leftarrow (-1 \times Change\%LR_t)$

else

$RtoD1_t \leftarrow RtoD2_t$

and

$RtoD2_t$:

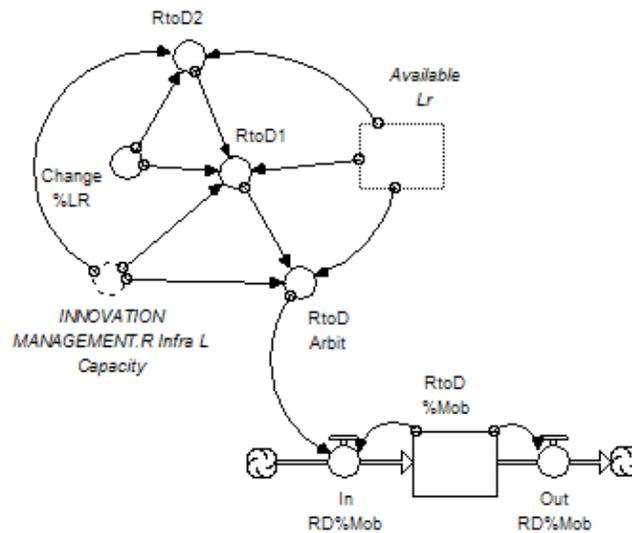


Figure 3.23: Research-to-Development Labor Mobility Process

if $AvailableLr_t < RInfraLCapacity_t$ **then**
 $RtoD2_t \leftarrow (+1 \times Change\%LR_t)$
else
 $RtoD2_t \leftarrow 0$

The last area in this module discusses the role that natural and genetic resources play in both the discovery of new knowledge and in the processes of innovation production. Being these two areas of great concern for interviewed actors from both nations, the dynamics of each is introduced into the model in particular segments.

The first of these segments explains how the stock of genetic resources varies as researchers engage in bio-prospection activities in a quest to identify and isolate the genes and genetic sequences within specific organism's DNA structures that help express particular traits.⁴¹

⁴¹Although neither Spain nor Mexico have explicit access to genetic resources for biotech regulation, this mechanism gathers from others set within plant variety and seeds production regulation and norms available in both countries for the access of these resources for food production and agriculture. These—in the opinion of some interviewed actors in Mexico—could serve as reference for the future design of such regulation locally.

The obtained information can then become new knowledge and perhaps serve as the basis for the creation of new innovations. Two stocks define the bio-prospection process in the model through the equations:

$$GeneDepRate_t = \int_0^t (InGRDep_t - OutGRDep_t)dt + GeneDepRate_{t-1} \quad (3.58)$$

and

$$GeneRes_t = \int_0^t (InGeneRes_t - OutGeneRes_t)dt + GeneRes_{t-1} \quad (3.59)$$

Where $GeneDepRate_t$ is the stock whose level represents the rate at which genetic resources are being accessed and, therefore, protected; $InGRDep_t$ is the inflow into this stock representing the degree of change in the access to these resources; $OutGRDep_t$ is the balancing output of this stock that allows it to represent the level of change every dt ; and $GeneDepRate_{t-1}$ is the initial rate at which genetic resources are accessed, set here at 2. In the second equation, $GeneRes_t$ represents the level of existing genetic resources already prospected; $InGeneRes_t$ is the inflow representing the level of new prospected genes, or successful finding of new genes; $OutGeneRes_t$ is the outflow of genetic resources that cannot become protected under IPR law and, therefore, its access does not require licensing; and $GeneRes_{t-1}$ is the initial level of this stock, set here at 10 million (see figure 3.24).

In the first equation, the inflow level for $InGRDep_t$ is defined by a logical function that determines whether the bio-prospection rate increases — suggesting a higher level of information finding and, therefore, a reduction in the free-access genetic information available in natural state— or decreases — reflecting a lack of success in research activities searching for novel information within these bio-prospected resources and thus, increasing the free-access ge-

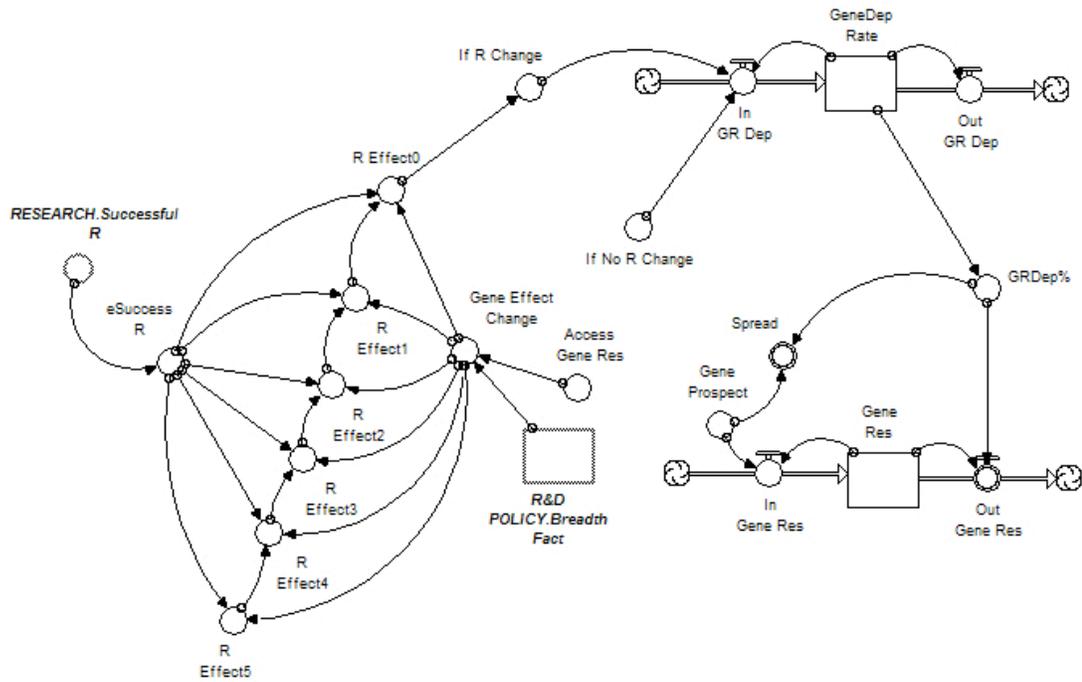


Figure 3.24: Genetic Resources Bio-Propecting Process

netic information in nature— in the model. The function defined within this flow is:

InGRDep_t:

if *IfRChange_t* > 0 **then**

$$InGRDep_t \leftarrow (GeneDepRate_t - IfRChange_t)$$

else

$$InGRDep_t \leftarrow (GeneDepRate_t + IfNoRChange_t)$$

In this function, *IfRChange_t* represents the degree of change at which the rate of bio-prospection varies, if research is indeed successful, each *dt*; while *IfNoRChange_t* displays the alternative fixed level of genetic resource growth, used by the process when research does not manage to successfully discover useful information with potential to become protected by IPR at *dt* and thus, allowing the stock of raw genetic information to marginally increase. The former, accordingly, is the last link of a process defining the degree at which the rate

of genetic resources being accessed and, therefore, protected by IPR, changes. This process —composed by the converters $REffect0_t$ through $REffect5_t$ — also relies on research’s degree of success given by $SuccessR_t$, originally defined within the *Research* module and represented here in natural numbers by the converter $eSuccessR_t$ ⁴²; the IPR breadth factor $BreadthFact_t$, described in the *R&D Policy* module; $AccessGenRes_t$ as the estimated percentage of all genetic resources accessed, set in the model at 10%; and the absolute amount of information obtained from genetic resources, $GeneEffectChange_t$, defined by the product of $AccessGenRes_t$ and $BreadthFact_t$. The logical functions within the converters defining this mechanism are:

$REffect0_t$:

if $eSuccessR_t = 0$ **then**

$REffect0_t \leftarrow (GeneEffectChange_t \times eSuccessR_t)$

else

$REffect0_t \leftarrow REffect1_t$

$REffect1_t$:

if $eSuccessR_t > 10,000,000$ **then**

$REffect1_t \leftarrow GeneEffectChange_t$

else

$REffect1_t \leftarrow REffect2_t$

$REffect2_t$:

if not ($eSuccessR_t > 10,000,000$ **or** $eSuccessR_t = 0$) **and**
 $eSuccessR_t > 5,000,000$ **then**

$REffect2_t \leftarrow (0.5 \times GeneEffectChange_t)$

else

⁴²Like in previous processes, $eSuccessR_t$ begins the Ln-to-natural number process using the transformation:

$$eSuccessR_t = e^{SuccessR_t} \quad (3.60)$$

$$REffect2_t \leftarrow REffect3_t$$

REffect3_t:

if not ($eSuccessR_t > 5,000,000$) **and** $eSuccessR_t > 2,000,000$

then

$$REffect3_t \leftarrow (0.25 \times GeneEffectChange_t)$$

else

$$REffect3_t \leftarrow REffect4_t$$

REffect4_t:

if not ($eSuccessR_t > 2,000,000$) **and** $eSuccessR_t > 1,000,000$

then

$$REffect4_t \leftarrow (0.1 \times GeneEffectChange_t)$$

else

$$REffect4_t \leftarrow REffect5_t$$

and

REffect5_t:

if not ($eSuccessR_t > 1,000,000$) **and** $eSuccessR_t > 1$ **then**

$$REffect5_t \leftarrow (0.01 \times GeneEffectChange_t)$$

else

$$REffect5_t \leftarrow 0$$

In the second equation, the level of $InGeneRes_t$ is given by the product of $GeneProspect_t$, which defines how growth in bio-prospection techniques increase the genetic resources available for research, and the stock of genetic resources available $GeneRes_t$; while $OutGeneRes_t$ is given also by the product of $GeneDepRate_t$ —as given in percent terms by the variable $GRDep\%_t$ —and the stock of genetic resource available set by $GeneRes_t$.

Finally, both the stock of genetic resource available, $GeneRes_t$, and $GRDep\%_t$ compose the converted $Spread_t$, which provides the difference (spread) between the bio-prospection capacity rate and the actual rate of success in bio-prospecting, used as a policy decision-making parameter within the IPR policy process in the *R&D Policy* module.

The second segment in this area, and last for this module, explains the general behavior of natural resources. Within this frame, natural resources display a duality that makes them not only be considered the necessary inputs within development endeavors, but also bearers of the effects of new biological discoveries and products. Ergo, reliant on the biosafety protection available to guarantee their sustainable balance. The main equations in this process are:

$$DepletionRate_t = \int_0^t (InDR_t - OutDR_t)dt + DepleteRate_{t-1} \quad (3.61)$$

and

$$NatResDev_t = \int_0^t (NatResReg_t - NatResDep_t)dt + NatResDev_{t-1} \quad (3.62)$$

Where $DepletionRate_t$ is the rate at which natural resources are depleted by their use in development; $InDR_t$ is the inflow of change that the depletion rate incurs in every dt ; $OutDR_t$ is the balancing outflow that allows measuring natural resources' depletion rate each dt ; and $DepleteRate_t$ is the natural resource depletion rate's initial level, set in the model at 2 (see figure 3.25).

In the first equation, $InDR_t$ is also given by a logical function that determines whether the natural resource depletion rate varies, increasing when the levels of biosafety —defined by the stock of industrial biosafety resources— increase, and reduces when the opposite happens. The function defined within this flow is:

$InDR_t$:

if $IfChange_t > 0$ **then**

$$InDR_t \leftarrow (DepletionRate_t - IfChange_t)$$

else

$$InDR_t \leftarrow (GeneDepRate_t + IfNoChange_t)$$

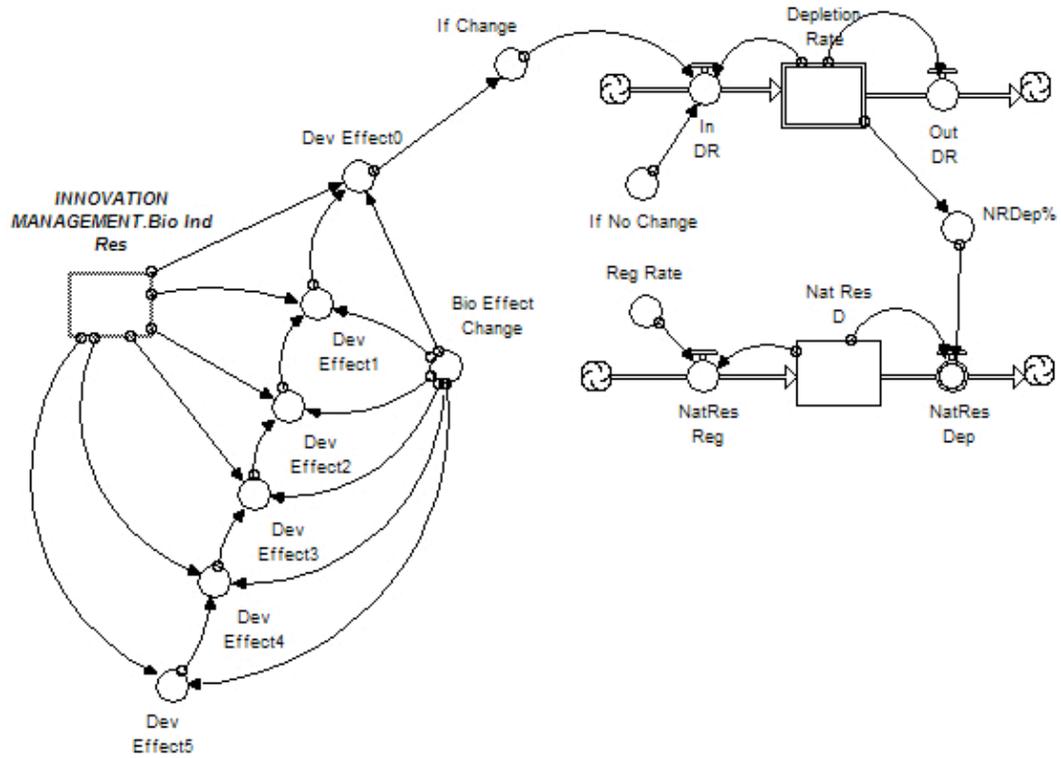


Figure 3.25: Natural Resources Balance Process

Here, $IfChange_t$ depends on the outcome of a mechanism that defines the degree of change at which the depletion rate of natural resources varies every dt . If this mechanism assesses a high level of biosafety resources, $BioIndRes_t$, as specified within the *Innovation Management* module, then the overall depletion rate reduces itself by a fraction defined by the converter $IfNoChange_t$, set in the process at 2%. In cases when the opposite happens, the depletion rate increases by a level determined by this mechanism. A series of logical functions —set by the converters $DevEffect0_t$ to $DevEffect5_t$ — along with the parameter $BioEffectChange_t$ —set at 5%— and the level of biosafety resources, $BioIndRes_t$, provide the degree of change at which the depletion rate of natural resources increases each dt . The logical functions within these converters are:

$$DevEffect0_t:$$

if $BioIndRes_t > 10,000,000$ **then**
 $DevEffect1_t \leftarrow BioEffectChange_t$
else
 $DevEffect1_t \leftarrow DevEffect2_t$

$DevEffect1_t$:

if $BioIndRes_t = 0$ **then**
 $DevEffect0_t \leftarrow (BioEffectChange_t \times BioIndRes_t)$
else
 $DevEffect0_t \leftarrow DevEffect1_t$

$DevEffect2_t$:

if not ($BioIndRes_t > 10,000,000$ **or** $BioIndRes_t = 0$) **and**
 $BioIndRes_t > 9,000,000$ **then**
 $DevEffect2_t \leftarrow (0.5 \times BioEffectChange_t)$
else
 $DevEffect2_t \leftarrow DevEffect3_t$

$DevEffect3_t$:

if not ($BioIndRes_t > 9,000,000$) **and** $BioIndRes_t >$
 $8,500,000$ **then**
 $DevEffect3_t \leftarrow (0.25 \times BioEffectChange_t)$
else
 $DevEffect3_t \leftarrow DevEffect4_t$

$DevEffect4_t$:

if not ($BioIndRes_t > 8,500,000$) **and** $BioIndRes_t >$
 $5,000,000$ **then**
 $DevEffect4_t \leftarrow (0.1 \times BioEffectChange_t)$
else
 $DevEffect4_t \leftarrow DevEffect5_t$

and

$DevEffect5_t$:

if not ($BioIndRes_t > 5,000,000$) **and** $BioIndRes_t > 1,000,000$ **then**
 $DevEffect5_t \leftarrow (0.01 \times BioEffectChange_t)$
else
 $DevEffect5_t \leftarrow 0$

To conclude, in the second equation, the level of $NatResReg_t$ is given by the product of $RegRate_t$, which defines the natural resources regeneration rate and the stock of natural resource available $NatResD_t$; while $NatResRep_t$ is the result of the product of $DepletionRate_t$ —given in percent terms by the variable $NRDep\%_t$ —and the stock of total natural resource available $NatResD_t$.

R&D Policy

The last module in this general model explains the role of policy and regulation in the promotion of research and innovation in biotech. Here, the government emerges as the facilitator and policing entity in charge of setting the limits and reaches of the existing regulatory frames in a quest to induce advancement in the sector. Within the various segments of this module, variables capturing the adapting capacity of these policy frameworks are analyzed to estimate the dynamics followed by these when coping with the fast-paced changes induced by discovery and innovation in modern biotech. The influence of and the need for abiding to regional and international standards are also considered here as pivotal factors defining these policies and their shaping dynamics. The module is divided into four areas: 1) IPR policy; 2) biosafety policy; 3) health inspection and protection policy; and 4) R&D promotion.

In the first area, rules defining intellectual property rights are explored as these help define breadth and length, the two central components of patent law within IPR regulation. These two traits are introduced in the model due to the

fact that these are considered essential for the study of patent dynamics (O'Donoghue 1996; O'Donoghue, Scotchmer and Thisse, 1995; Green and Scotchmer, 1995).

The two central stock in this segment explain how the breadth —defined as the amount of information within genetic resources over which a patent can be claimed— and the overall effect of patent protection within the IPR system — as defined by a factor composed by the breadth level and length of protection these rights are provided for— behave over time. The equations for these are:

$$BreadthFact_t = \int_0^t (InBFact_t - OutBFact_t)dt + BreadthFact_{t-1} \quad (3.63)$$

and

$$IPREffect_t = \int_0^t (InIPR_t - OutIPR_t)dt + IPREffect_{t-1} \quad (3.64)$$

Where $BreadthFact_t$ is the breadth level expressed as a stock; $InBFact_t$ is the degree of change at which the breadth level changes every dt ; $OutBFact_t$ is the balancing outflow for the stock; and $BreadthFact_{t-1}$ is the initial breadth level. In the second equation, $IPREffect_t$ is the factor composed by the degree of both breadth and length defined as a stock; $InIPR_t$ is the inflow defining the stock's degree of change every dt ; $OutIPR_t$ is the stock's balancing outflow; and $BreadthFact_{t-1}$ is the initial level of this stock (see figure 3.26).

In the first equation, the inflow $InBFact_t$ is in function of the effective appropriation rate, $EffectiveAppRate_t$, and the slider input device, $BreadthFact_t$, which defines the degree of breadth at the model's interface level.

The inflow is defined by the function:

$$InBFact_t = Breadth_t + EffectiveAppRate_t$$

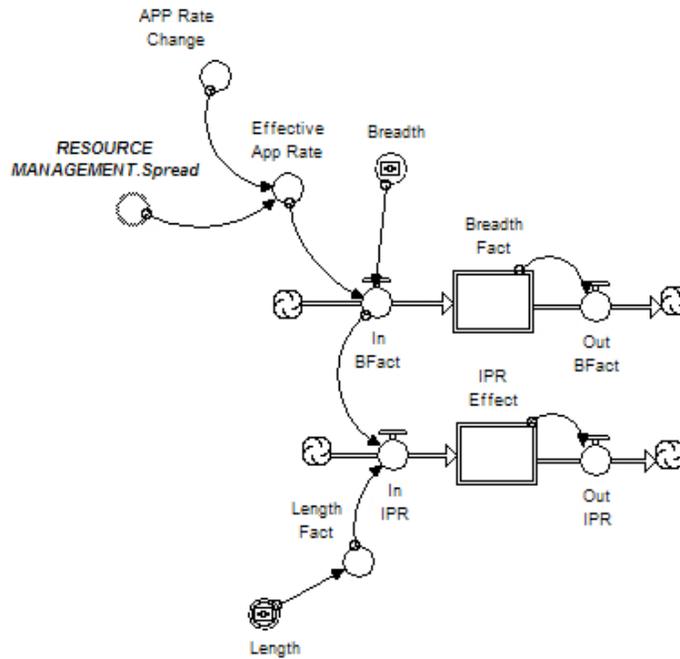


Figure 3.26: IPR Policy Process

Further, $EffectiveAppRate_t$ is given by a logical function that sets the amount the effective appropriation rate changes as a function of the spread between the genetic resources' depletion and prospection rates, $Spread_t$, defined within the *Resource Management* module, and a fixed appropriation rate of change, $APPRateChange_t$, set in the model at -1%. The logical function within this converter is:

$EffectiveAppRate_t$:

if $Spread_t > 0.25$ **then**

$EffectiveAppRate_t \leftarrow APPRateChange_t$

else

$EffectiveAppRate_t \leftarrow 0$

On the other hand, the outflow $OutBFact_t$ is defined by total stock of $BreadthFact_t$ every dt .

In the second equation, the inflow $InIPR_t$ is in function of the degree at which the breadth level changes every dt , $InBFact_t$, and the patent lifetime length, $LengthFact_t$, and is given by the logical function:

$InIPR_t$:

if ($InBFact_t \times LengthFact_t$) < 1 **then**
 $InIPR_t \leftarrow (InBFact_t \times LengthFact_t)$
else
 $InIPR_t \leftarrow 1$

Here, the length factor, $LengthFact_t$, is also in function of the slider input device, $Length_t$, which sets the patent's length at the model's interface level. The general patent's lifetime length is —on average— 25 years, so in order to calculate the proportion of change, the length given by the model is divided by this number. This inflow is defined by the function:

$$LengthFact_t = \frac{Length_t}{25}$$

Finally, the outflow $OutIPR_t$ is also defined by total stock of $IPREffect_t$ every dt .

The second area in this module explains how the minimum levels of biosafety are set by the government as it simultaneously aims at reducing the depletion of natural resources, easing public worry, and complying with international standards. The single stock defined here sets the levels of biosafety within the model and shows how these change as natural resources or public perception vary.⁴³

The equation for this stock is:

⁴³The notion of public perception is introduced in this model to capture the relevance it has in shaping the limits of the regulation and oversight rules that the processes and outcomes of this technology have to abide to. As reported by actors from both Spain and Mexico, these can either allow processes to move forward more rapidly (case of medicine approval in Spain) or doom particular products (case of GM papaya in southeast Mexico).

$$BiosafetyLevel_t = \int_0^t (InBLEv_t - OutBLEv_t) + BiosafetyLevel_{t-1} \quad (3.65)$$

Where $BiosafetyLevel_t$ is the minimum level of biosafety the industry needs to subject its innovation production activities to; $InBLEv_t$ is the the degree of inflow changing the level of this stock every dt ; $OutBLEv_t$ is the stock balancing outflow; and $BiosafetyLevel_{t-1}$ is the stock's initial level (see figure 3.27).

The inflow $InBLEv_t$ is in function of international biosafety standards, given by $IntlBioStandad_t$ (set in the general model at 2.15); the levels of the variable capturing the effects of public perception, $PPEffect_t$; and the degree of biosafety represented as a stock, $BiosafetyLevel_t$. This is defined by the logical function:

$InBLEv_t$:

if ($BiosafetyLev_t + PPEffect_t$) > $IntlBioStandad_t$ **then**
 $InBLEv_t \leftarrow [(BiosafetyLev_t + PPEffect_t)-1]$
else
 $InBLEv_t \leftarrow (BiosafetyLev_t + PPEffect_t)$

In this process, public perception $PublicPerception_t$ is in function of the difference between the public depletion threshold, $PubDepThres_t$ —which is equal to the international biosafety standard, $IntlBioStandad_t$ — and the natural resources depletion rate, $DepletionRate_t$, defined within the *Resource Management* module. The equation for this function is:

$$PublicPerception_t = DepletionRate_t - PubDepThres_t$$

On the other hand, public perception as an effect, $PPEffect_t$, is in function of $PublicPerception_t$ and its level is defined by a logical function:

$PPEffect_t$:

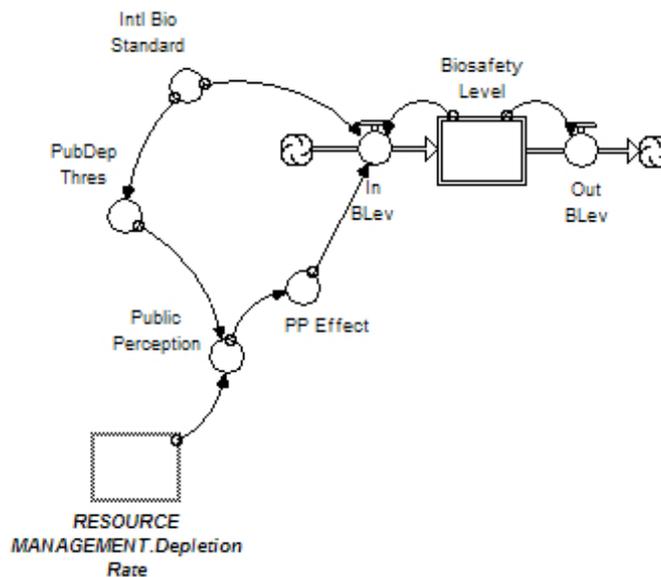


Figure 3.27: Biosafety Policy Process

```

if  $PublicPerception_t > 0$  then
     $IPPEffect_t \leftarrow 0.01$ 
else
     $PPEffect_t \leftarrow 0$ 

```

This process guarantees that the biosafety level increases whenever the stock of natural resources becomes affected beyond the limits of public acceptance. Finally for this section, $OutBlev_t$ is defined by total $BiosafetyLevel_t$ every dt .

The third area in this module focuses on health inspection and protection policy, displaying how the health safety rate in the model varies and thus, alters the cost of health inspection procedures performed by the government's net of health safety inspection services. The first stock in this process captures how the rate of health inspection services varies or, in other words, how the proportion of capital earnings the development industry (i.e. biopharmaceuticals, food developers, animal use, etc.) has to pay to get their products approved before reaching the market varies.

The single stock in this process is:

$$HealthSafetyRate_t = \int_0^t (InHSR_t - OutHSR_t) + HealthSafetyRate_{t-1} \quad (3.66)$$

Where $HealthSafetyRate_t$ is a stock that represents health safety rate as a proportion of development's income; $InHSR_t$ is the inflow defined as a rate of change for this stock every dt ; $OutHSR_t$ is the balancing flow that allows knowing the stocks level every dt ; and $HealthSafetyRate_{t-1}$ is the stock's initial rate. The inflow $InHSR_t$ is equal to the international health safety rate standard, towards which the initial stock moves as it seeks global standardization for local processes. The balancing outflow, $OutHSR_t$, in this process is equal to the level of the stock represented by $HealthSafetyRate_t$ every dt (see figure 3.28).

The second segment in this area explains how the actual amount of capital resources required by the industry to undergo health inspection —given in the model's knowledge units currency— varies every dt . The lone stock in this process explains the dynamics of this amount as it varies over time. The equation of this stock is:

$$HSInspectLevel_t = \int_0^t (InHSIL_t - OutHSIL_t) + HSInspectionLevel_{t-1} \quad (3.67)$$

Where $HSInspectLevel_t$ is the cost of health inspection for innovation activities, represented as a stock; $InHSIL_t$ is the inflow of resources changing this stock every dt ; $OutHSIL_t$ is the balancing outflow for this stock; and $HSInspectLevel_{t-1}$ is the initial cost of health inspection.

The inflow $InHSIL_t$ is equal to the parameters $HSCChange_t$, which is the last link of a brief logical function mechanism. Within this mechanism, this last parameter together with $HSCChange_1_t$ define how much the amount required for health inspection varies every dt . These parameters are both in function

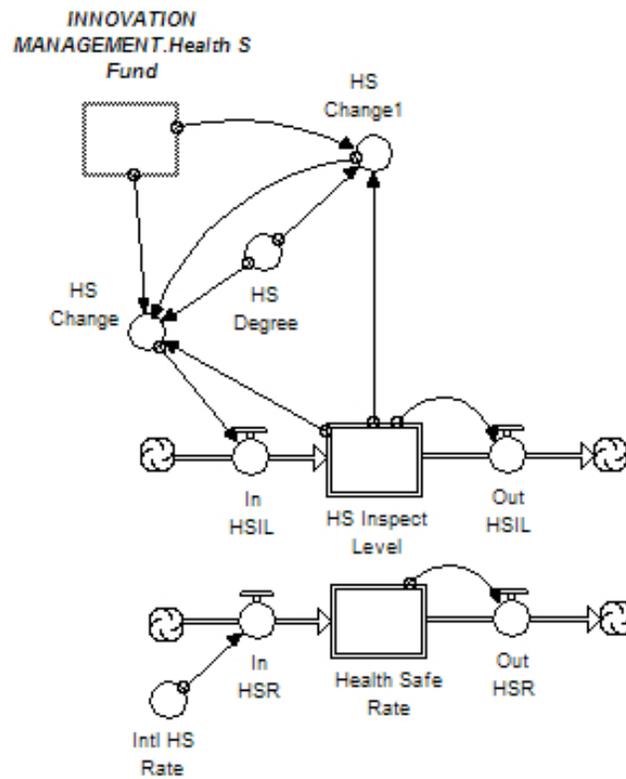


Figure 3.28: Health Safety Policy Process

of health inspection costs, $HSInspectLevel_t$; the level of health inspection resources, $HealthSFund_t$, defined within the *Innovation Management* module; and a fixed change proportion, given by $HSDegree$, and set in the model at 5,000. The logical functions defining this process are:

$HSChange_t$:

```

if  $HealthSFund_t < 10,000,000$  then
     $HSChange_t \leftarrow (HSInspectLevel_t + HSDegree)$ 
else
     $HSChange_t \leftarrow HSChange1_t$ 
  
```

and

$HSChange1_t$:

```

if not ( $HealthSFund_t < 10,000,000$ ) then
  
```

$$\begin{aligned}
& HSChange1_t \leftarrow (HSInspectLevel_t - HSDegree) \\
\mathbf{else} \\
& HSChange1_t \leftarrow 0
\end{aligned}$$

This mechanism helps define the degree and sign of the inflow $InHSIL_t$ going into the cost of health inspection for innovation activities. Also in this segment, the balancing outflow, $OutHSIL_t$, is equal to the level of the stock represented by $HSInspectLevel_t$ every dt (also see figure 3.28).

Finally, the last area in this module focuses on R&D promotion as expressed through direct investment in these two areas and in research infrastructure. The three stock composing this area explain the tax rate as income government; the amount of these resources going to government-funded R&D activities; and the amount of these invested in research infrastructure. The equations for these stock are:

$$TaxRate_t = \int_0^t (InTaxChange_t - OutTaxChange_t) + TaxRate_{t-1} \quad (3.68)$$

$$R\&DRate_t = \int_0^t (InR\&DRate_t - OutR\&DRate_t) + R\&DRate_{t-1} \quad (3.69)$$

and

$$InfraRate_t = \int_0^t (InInfraRate_t - OutInfraRate_t) + InfraRate_{t-1} \quad (3.70)$$

Where $TaxRate_t$ is the official government tax rate, defined as a stock; $InTaxChange_t$ is the inflow as degree of change going into this stock; $OutTaxChange_t$ is the stock's balancing outflow; and $TaxRate_{t-1}$ is the initial tax rate, set in the model at 35% (similar in both Spain and Mexico). In the second equation $R\&DRate_t$ is the percentage of government resources allocated for research and development in biotech activities; $InR\&DRate_t$ is the

inflow as level of change that this percentage varies each dt ; $OutR\&DRate_t$ is the stock's balancing outflow; and $R\&DRate_{t-1}$ is the initial percentage of resources going to R&D, set in the model at 84%. For the last equation, $InfraRate_t$ is the percentage of government resources allotted to renewing or creating research infrastructure; $InInfraRate_t$ is the inflow as degree of change that this percentage varies each dt ; $OutInfraRate_t$ is the stock's balancing outflow; and $InfraRate_{t-1}$ is the initial percentage of government resources going to infrastructure (see figure 3.29).

In the initial equation, the inflow $InTaxChange_t$ is given by the sum:

$$InTaxChange_t = TaxRate_t + T1_t$$

The parameter $T1_t$, along with its counterpart $T2_t$; a degree of change given by $TaxRateChange_t$ (set in the model at 1%); and $NetResGovt_t$, previously defined within the *Resource Management* module, provide a fraction of change that taxes face each dt through a succinct logical function mechanism. The logical functions for this process are:

$T1_t$:

if $NetResGovt_t > 1,000,000$ **then**

$$T1_t \leftarrow TaxRateChange_t$$

else

$$T1_t \leftarrow T2_t$$

and

$T2_t$:

if $NetResGovt_t < 10,000$ **then**

$$T2_t \leftarrow (-1 \times TaxRateChange_t)$$

else

$$T2_t \leftarrow 0$$

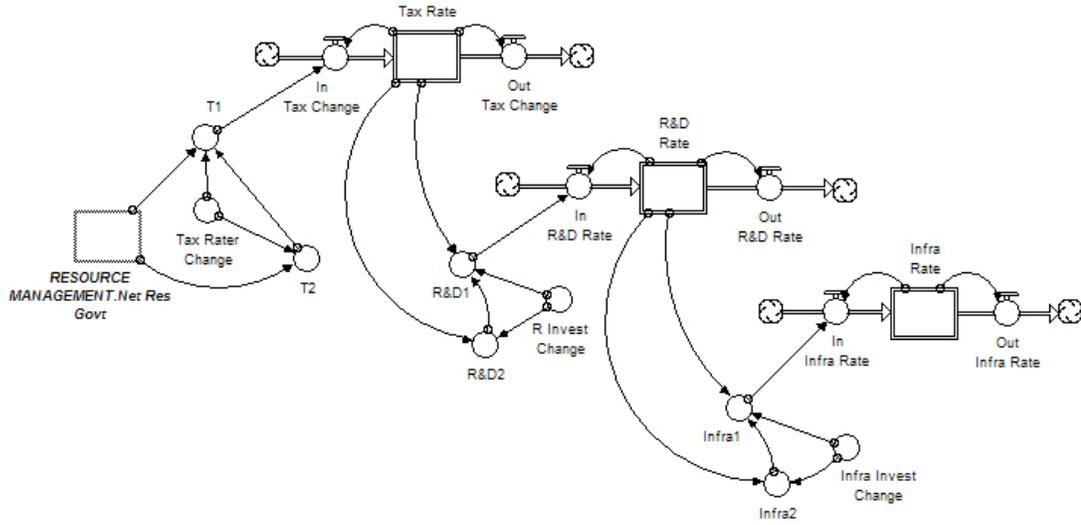


Figure 3.29: R&D Promotion Policy Process

Lastly, the balancing outflow, $OutTaxChange_t$, is also equal to the level of the stock represented by $TaxRate_t$ every dt .

In the second equation, the inflow $InR\&DRate_t$ is given by the sum:

$$InR\&DRate_t = R\&DRate_t + R\&D1_t$$

In quite an analogous way to the previously explained process, through a logical function mechanism composed by the parameters $R\&D1_t$ and $R\&D2_t$; a degree of change given by $RInvestChange_t$ (set in the model at 0.1%); along with the previously defined $TaxRate_t$, provide a fraction of change that R&D expresses each dt . The logical functions for this process are:

$R\&D1_t$:

```

if  $TaxRate_t > 35\%$  then
     $R\&D1_t \leftarrow RInvestChange_t$ 
else
     $R\&D1_t \leftarrow R\&D2_t$ 

```

and

$R\&D2_t$:

if $TaxRate_t < 35\%$ **then**
 $R\&D2_t \leftarrow (-1 \times RInvestChange_t)$
else
 $R\&D2_t \leftarrow 0$

The balancing outflow, $OutR\&DRate_t$, is as well equal to the level of the stock represented by $R\&DRate_t$ every dt (also see figure 3.29).

Finally, in the last equation, the inflow $InInfraRate_t$ is given by the sum:

$$InInfraRate_t = InfraRate_t + Infra1_t$$

Just as the previous two process, through a logical function mechanism comprised by the parameters $Infra1_t$ and $Infra2_t$; a degree of change given by $RInfraChange_t$ (set in the model also at 0.1%); as well as with the previously defined $TR\&DRate_t$, give description to the fraction of change that research infrastructure expresses each dt . The logical functions for this process are:

$Infra1_t$:
if $R\&D_t > 84\%$ **then**
 $Infra1_t \leftarrow InfraInvestChange_t$
else
 $Infra1_t \leftarrow Infra2_t$

and

$Infra2_t$:
if $R\&DRate_t < 60\%$ **then**
 $Infra2_t \leftarrow (-1 \times InfraInvestChange_t)$
else
 $Infra2_t \leftarrow 0$

To finalize this section, the balancing outflow, $OutInfraRate_t$, is as well equal to the level of the stock represented by $InfraRate_t$ every dt (also see figure 3.29).

3.2 System Performance Assessment

The complex task of analyzing and comparing the results of each set of changes that could be introduced to the general model called for a more sophisticated assessment process. This entailed the design of a methodology that could measure the effects of structural and parametric changes (or combinations of these) on the model's performance while also taking into account its intrinsic stochastic character. This step would mainly focus on providing sufficient information to determine which of these changes induce significantly enough effects to modify the performance of specific key variables within the system. This section details the design of such an experiment.

3.2.1 Experiment Design

The initial modeling exercise *per se* provides a first glimpse of the existing structural differences between the two countries' systems of innovation by defining each as a variation of the designed general model. Yet, another central objective of this study is to estimate the effects that such differences—as single structural or parametric changes or combinations of these—have on the performance of the basic model once initial conditions for Spain and Mexico are introduced. To achieve this, an experiment that allows measuring and comparing the effects that these 'treatments' have on this system—as well as a comparison between its performance once a treatment is applied—was defined.⁴⁴ Such an experi-

⁴⁴The initial conditions for the general model were set as follows: Interest rate at 3%; price of knowledge units, 10; labor hand levels at 10,000 (with a research-to-development ratio of 3:1); level of existing research infrastructure at 10 million (requiring 1,000 units per research worker); level of existing infrastructure for development at 2 million (requiring 2,000 units per development worker); government resources, 10 million, with fixed funds to R&D at 0; net financial resources to research, 5 million; net financial resources to development, 5 million; venture capital funds 10 million; international venture capital available at 10 million (with 100,000 entering the fund each cycle and 1% of the total fund going to investment, when available); savings and

ment allowed observation and measurement of the effects that changes to specific structural and parametrical controlled factors⁴⁵ had on particular response variables of the system before specific initial conditions representing each country's MBTS were introduced.⁴⁶ However, due to the fact that treatments are formed by combinations of factors—in this case seven; five with two levels each and two with three, for a total of 288 possible treatments—a subset of 34 treatments was selected to study the relationship between these and the behavior of a sample of response variables (see table 3.1). Thus, the exercise was designed as a fractional factorial experiment. Furthermore, since the model has a stochastic component allowing it to yield different results every time—notwithstanding constant initial conditions—the experiment also samples results for each response variable from multiple runs.

spending both at 0; patents at 0; public knowledge at 100; IPR length at 25 years and breadth at 50%; the levels of natural resources and genetic resources at 10 million; biosafety at 10 million, with an inspection level of 100,000; and health safety all at 10 million, with an inspection level of 200,000; and new research and new development set both to a level of 1 to avoid divisions by zero.

⁴⁵These structural elements are: 1) the presence of venture capital investment (including international venture capital); 2) research clustering; 3) development clustering; 4) labor mobility between research and development; and 5) a “royalty-sharing” rule that establishes how the results of publicly funded research are to be allocated. The two parametric factors also working as control variables affect the behavior of IPRs by extending, reducing, or keeping constant the length (25 years) and the breadth (set at 50%) of IPR protection. A further structural element, defined as “match-making” is intrinsic to both, the venture capital variable and the clustering elements in the model. When venture capital is present in the model, these two effects encourage investment in either sector (R or D) when either displays both low financial resources and a high payback probability (as measured by its debt/income ratio), or suggest the existence of a “common objective” that encourages intra-sector collaboration at any given *dt*. Yet another switch within the model represents the presence of a fixed amount of funds for R&D. However, due to the fact that both Spain and Mexico have such a fixed amount of resources per period this switch remains “on” in every model's version and run.

⁴⁶The set of selected response variables are: 1) new research (new knowledge); 2) research potential; 3) new development (new innovations); 4) development potential; 5) to market (new marketable products); 6) patented knowledge; 7) open access knowledge; 8) research infrastructure capacity; 9) development infrastructure capacity; 10) government income; 11) venture capital to research; 12) venture capital to development; 13) level of existing genetic resources; 14) biosafety level; and 15) health safety inspection level. Although the model displays other response variables, these were not assessed in this process. Among these are: resources to research coming from tech transfer to research; resources to research coming from tech transfer to development; R&D's savings and expenditure level; and labor hand going to research and

Table 3.1: Selected Treatment Subset

	Structural Elements ¹					Parametric Factors ²	
	RC	DC	LM	VC	RR	IPRL ³	IPRB ⁴
All Off	-	-	-	-	-	=	=
All On	+	+	+	+	+	=	=
DC	-	+	-	-	-	=	=
LM	-	-	+	-	-	=	=
Off+IPRB	-	-	-	-	-	=	+
Off+IPRL	-	-	-	-	-	+	=
Off+IPRL+IPRB	-	-	-	-	-	+	+
Off+IPRL-IPRB	-	-	-	-	-	+	-
Off+IPRL-IPRB+LM	-	-	+	-	-	+	-
Off+IPRL-IPRB+RC	+	-	-	-	-	+	-
Off+IPRL-IPRB+RC+LM	+	-	+	-	-	+	-
Off-IPRB	-	-	-	-	-	=	-
Off-IPRL	-	-	-	-	-	-	=
Off-IPRL+IPRB	-	-	-	-	-	-	+
Off-IPRL-IPRB	-	-	-	-	-	-	-
Off-IPRL-IPRB+LM	-	-	+	-	-	-	-
Off-IPRL-IPRB+RC	+	-	-	-	-	-	-
On+IPRB	+	+	+	+	+	=	+
On+IPRL	+	+	+	+	+	+	=
On+IPRL+IPRB	+	+	+	+	+	+	+
On+IPRL-IPRB	+	+	+	+	+	+	-
On-IPRB	+	+	+	+	+	=	-
On-IPRL	+	+	+	+	+	-	=
On-IPRL+IPRB	+	+	+	+	+	-	+
On-IPRL-IPRB	+	+	+	+	+	-	-
On-LM	+	+	-	+	+	=	=
RC	+	-	-	-	-	=	=
RD+DC	+	+	-	-	-	=	=
RD+DC+LM	+	+	+	-	-	=	=
RD+DC+VC	+	+	-	+	-	=	=
RR	-	-	-	-	+	=	=
RR+LM	-	-	+	-	+	=	=
VC	-	-	-	+	-	=	=
VC+RR	-	-	-	+	+	=	=

¹ The structural elements are: Research Clustering (RC), Development Clustering (DC), Labor Mobility (LM), Venture Capital (VC) including international VC, and Research Royalty Rule (RR)

² The parametric factors are: IPR Length (IPRL), and IPR Breadth (IPRB)

³ Changes to this parametric factor are: Increase (IPRL+10),decrease (IPRL-10)

⁴ Changes to this parametric factor are: Increase (IPRB+0.25),decrease (IPRB-0.25).

To obtain observations of significant statistical value the model was run 100 times per treatment, recording and analyzing the behavior of the selected response variable for each time period.⁴⁷ The mean for each time period of simulation (meaning the arithmetic mean of 100 observations per dt) was obtained and used to define a single general observation per dt for each response variable per treatment. Later, these more manageable data were used to run time series regressions to obtain the trend lines that describe the effects that each of the treatments have on the response variables over time (see table 3.2).⁴⁸ The equations for these trend lines provided necessary and sufficient information to allow making a direct comparison between treatments and, thus, between the results (effect on response variables) provided by different versions of the model. Furthermore, these allowed estimating which of the selected 34 treatments were indeed those with the most significant effects. Consequently, this also allowed testing **the probability of obtaining a series of responses that are likely or more likely to allow rejecting the H_0 (null hypothesis) which suggests that the presence of five structural elements and specific changes to parametric variables in the general model does not increase the response of specific variables.**

development.

⁴⁷All versions of the model were ran using the Euler's integration method with a simulation length going from 0 to 25 and a dt equal to 0.5. This means that every time the model was run, it provided two levels per time for each response variable, a total of 50 per run.

⁴⁸With the use of statistical analysis software (MINITAB) the fitted trend lines were set to be quadratic trend of the form:

$$Y_t = \beta_0 + \beta_1 \cdot t + (\beta_2 \cdot t^2) + e_t$$

based on the better-fit information provided by the Measures of Accuracy. These measures are: Mean Absolute Percentage Error (MAPE), which expresses the accuracy as a percentage of the error; Mean Absolute Deviation (MAD), which expresses the accuracy in the same units as the data; and the Mean Squared Deviation (MSD), a commonly-used measure of accuracy for fitted series values.

Table 3.2: Effect of Selected Treatments on “New Development” Response Variable: Equation Parameters

Treatment	Equation Parameters ¹					
	MAPE	MAD	MDS	β_0	β_1	β_2
All Off	18.3342	0.4931	0.3503	2.4870	0.0811	-0.001280
All On	14.9660	0.4071	0.3074	2.7810	0.0665	-0.001101
DC	13.4224	0.3448	0.2159	2.428	0.0966	-0.001622
LM	12.4086	0.3205	0.1939	2.293000	0.095300	-0.001417
Off+IPRB	17.1271	0.4047	0.3051	2.513000	0.094700	-0.001596
Off+IPRL	17.0463	0.4215	0.3651	2.692000	0.076000	-0.001298
Off+IPRL+IPRB	15.8934	0.4019	0.3244	2.608000	0.088100	-0.001416
Off+IPRL-IPRB	15.7021	0.4161	0.2971	2.321000	0.115000	-0.001950
Off+IPRL-IPRB+LM	15.2942	0.4025	0.2865	2.496000	0.086300	-0.001418
Off+IPRL-IPRB+RC	13.8249	0.3703	0.2451	2.553000	0.088500	-0.001469
Off+IPRL-IPRB+RC+LM	15.2101	0.3554	0.2429	2.453000	0.094000	-0.001550
Continued ...						

Table 3.2: (continued)

Treatment	Equation Parameters ¹					
	MAPE	MAD	MDS	β_0	β_1	β_2
Off-IPRB	13.6394	0.3613	0.2304	2.292000	0.118000	-0.002029
Off-IPRL	14.1515	0.3483	0.2392	2.580000	0.074500	-0.001099
Off-IPRL+IPRB	15.5441	0.3798	0.3077	2.804000	0.057200	-0.000860
Off-IPRL-IPRB	15.661	0.3786	0.2497	2.216000	0.124300	-0.002103
Off-IPRL-IPRB+LM	15.0046	0.4070	0.2713	2.330000	0.092900	-0.001399
Off-IPRL-IPRB+RC	14.7213	0.3924	0.2495	2.209000	0.099500	-0.001517
On+IPRB	15.3635	0.4032	0.2868	2.423000	0.096300	-0.001605
On+IPRL	12.9902	0.3309	0.2152	2.513000	0.074600	-0.001177
On+IPRL+IPRB	14.3728	0.4029	0.2781	2.385000	0.100300	-0.001610
On+IPRL-IPRB	15.9394	0.4200	0.3262	2.635000	0.081900	-0.001356
On-IPRB	13.8979	0.3852	0.2492	2.344000	0.117900	-0.001999
On-IPRL	14.8506	0.4010	0.2712	2.486000	0.088400	-0.001392
Continued ...						

Table 3.2: (continued)

Treatment	Equation Parameters ¹					
	MAPE	MAD	MDS	β_0	β_1	β_2
On-IPRL+IPRB	17.1671	0.4321	0.3486	2.567000	0.083300	-0.001289
On-IPRL-IPRB	15.1293	0.4149	0.3376	2.896000	0.067500	-0.001136
On-LM	14.2308	0.3595	0.2402	2.695000	0.063400	-0.001005
RC	13.6897	0.3774	0.2279	2.286000	0.107600	-0.001795
RC+DC	16.0286	0.4327	0.2893	2.246000	0.112500	-0.001841
RC+DC+LM	13.1379	0.3451	0.2323	2.682000	0.076400	-0.001310
RC+DC+VC	15.5031	0.4218	0.3111	2.603000	0.085000	-0.001491
RR	13.5641	0.3602	0.2314	2.559000	0.066600	-0.000948
RR+LM	16.5259	0.4191	0.3340	2.576000	0.093500	-0.001647
VC	14.4092	0.3720	0.2706	2.649000	0.066800	-0.000989
VC+RR	16.1599	0.4335	0.3137	2.551000	0.078100	-0.001269

¹ All parameters where obtained through the use of quadratic trend line models.

End

3.3 Results

3.3.1 General (or Non-Parametric) Model

This first stage of the experiment design allows testing the response of multiple variables within the general model when its initial conditions are set the closest to neutral. This facilitated sorting out which of the applied treatments may be more effective from those which may not, while also reducing any possible effects induced by more specific initial conditions. To better grasp how these response variables behave over time when the model is being subjected to each treatment, the results were evaluated at four different times: a) 1 year or $2dt$ (reference); b) 5 years or $10 dt$ (short term); c) 10 years or $20 dt$ (mid term); and d) 25 years or $50 dt$ (long term), using the parameters of the equations obtained through time series analysis for each variable to do so (see table 3.3). **These results were then assessed to determine: a) consistency** as the degree of response that each treatment induced on the variables at each time period; and **b) performance** as the percentage change that each of these responses had as compared to that of their level at year 1. The results obtained in each of these processes (consistency and performance) were ranked at each time period with respect to the neutral treatment (All Off). Lastly, a general rank to define each treatment's overall effectiveness was developed based on these performance and consistency levels.

As suggested, due to the large quantity of output generated by these initial testing procedures, presenting all obtained results deem to be quite an impractical task. Tables 3.2 to 3.5 show the results of the described analytical approach for the key "New Development" (or new innovation, $i1$ variable) found within the Development module and considered as one of the model's most significant

Table 3.3: Effect of Selected Treatments on “New Development” Response Variable: Response Per Term

Treatment	Response ¹			
	Term			
	Initial	Short	Mid	Long
All Off	2.644	3.170	3.597	3.342
All On	2.910	3.336	3.671	3.354
DC	2.615	3.232	3.711	3.203
LM	2.478	3.104	3.632	3.516
Off+IPRB	2.696	3.300	3.769	3.258
Off+IPRL	2.839	3.322	3.693	3.247
Off+IPRL+IPRB	2.779	3.347	3.804	3.473
Off+IPRL-IPRB	2.543	3.276	3.841	3.196
Off+IPRL-IPRB+LM	2.663	3.217	3.655	3.266
Off+IPRL-IPRB+RC	2.724	3.291	3.735	3.306
Off+IPRL-IPRB+RC+LM	2.635	3.238	3.713	3.278
Off-IPRB	2.520	3.269	3.840	3.120
Off-IPRL	2.725	3.215	3.630	3.558
Off-IPRL+IPRB	2.915	3.290	3.604	3.514
Off-IPRL-IPRB	2.456	3.249	3.861	3.174
Off-IPRL-IPRB+LM	2.510	3.119	3.628	3.478
Off-IPRL-IPRB+RC	2.402	3.052	3.592	3.392
On+IPRB	2.609	3.226	3.707	3.226
On+IPRL	2.657	3.141	3.534	3.301

Continued . . .

Table 3.3: (continued)

Treatment	Response ¹			
	Term			
	Initial	Short	Mid	Long
On+IPRL+IPRB	2.579	3.227	3.747	3.375
On+IPRL-IPRB	2.793	3.318	3.731	3.340
On-IPRB	2.572	3.323	3.902	3.242
On-IPRL	2.657	3.231	3.697	3.426
On-IPRL+IPRB	2.728	3.271	3.717	3.510
On-IPRL-IPRB	3.026	3.457	3.792	3.431
On-LM	2.818	3.229	3.561	3.353
RC	2.494	3.183	3.720	3.179
RC+DC	2.464	3.187	3.760	3.269
RC+DC+LM	2.830	3.315	3.686	3.227
RC+DC+VC	2.767	3.304	3.707	3.126
RR	2.688	3.130	3.512	3.519
RR+LM	2.756	3.346	3.787	3.134
VC	2.779	3.218	3.589	3.517
VC+RR	2.702	3.205	3.605	3.284

¹ Parameters obtained through the use of quadratic trend line models.

End

variables. This variable—which displays the number of new marketable products or services created through the use of modern biotech per dt —serves as a suitable illustration of the behavior of all analyzed response variables⁴⁹

⁴⁹The results gathered from the Spain and Mexico versions of the model presented in subse-

As for all other response variables, when contrasting the effect of each treatment to that induced by the neutral treatment (All Off) at three time periods (5, 10, and 25 years) it was possible to estimate the difference in effect that each of these induced with respect to that of the reference policy.⁵⁰ By ranking these response levels at each term, it became possible to identify their degree as well as the fact that their behavior was not always consistent over time (see table 3.4). In some cases, these treatments promoted an unfavorable response in the short and mid runs as compared to that of the neutral treatment, only to better their performance drastically in the long run. A case displaying this tendency is that of the treatment suggesting no structural elements plus a reduction in the IPR length (Off-IPRL), which went from 25th in the short and mid terms, to the highest ranking in the long run. Other examples that started slow but later prompted higher responses are the research royalty rule (RR), which reached the second position from previously being the 31st and 34th, respectively, and venture capital (VC) and labor mobility (LM), which came back from 23rd and 33rd in the short term to 3rd and 4th, respectively, in the long term.

Other treatments showed the opposite behavior, like the conjunction of research royalty rule and labor mobility (RR+LM), which went from being the 3rd with the most response in the short run to the 32nd in the long run. Among those treatments inducing this response pattern is the treatment that suggests the presence of all structural elements (All On), having the 4th largest effect in the short run and decreasing to the 13th in the long run. Further treatments behaving like this are all structural elements present plus a reduction in IPR breadth (On+IPRB), which—in the mid-run—proved to induce the highest ef-

quent sections delve into the response and behavior of a wider range of variables (a total of 15, including the one reviewed in this section).

⁵⁰As mentioned earlier, in this and subsequent sections the terms model, treatment, and policy will be used indistinctly to refer to any of the treatments under scrutiny.

Table 3.4: Effect of Selected Treatments on “New Development” Response Variable: Rank and Change

Treatment	Rank			% Change ¹		
	Short	Mid	Long	Short	Mid	Long
All Off	29	29	15	0.000	0.000	0.000
All On	4	22	13	5.233	2.046	0.344
DC	18	16	28	1.950	3.175	-4.159
LM	33	24	4	-2.073	0.979	5.192
Off+IPRB	10	8	23	4.114	4.771	-2.513
Off+IPRL	6	20	24	4.801	2.663	-2.843
Off+IPRL+IPRB	2	5	8	5.596	5.744	3.920
Off+IPRL-IPRB	13	3	29	3.344	6.783	-4.369
Off+IPRL-IPRB+LM	24	23	22	1.489	1.607	-2.274
Off+IPRL-IPRB+RC	11	11	17	3.820	3.848	-1.092
Off+IPRL-IPRB+RC+LM	17	15	20	2.145	3.225	-1.915
Off-IPRB	15	4	34	3.126	6.767	-6.658
Off-IPRL	25	25	1	1.423	0.929	6.448
Off-IPRL+IPRB	12	28	5	3.785	0.195	5.147
Off-IPRL-IPRB	16	2	31	2.483	7.334	-5.042
Off-IPRL-IPRB+LM	32	26	7	-1.606	0.873	4.054
Off-IPRL-IPRB+RC	34	30	11	-3.713	-0.133	1.481
On+IPRB	22	17	27	1.751	3.058	-3.486
On+IPRL	30	33	18	-0.905	-1.746	-1.242
On+IPRL+IPRB	21	10	12	1.798	4.170	0.987

Continued . . .

Table 3.4: (continued)

Treatment	Rank			% Change ¹		
	Short	Mid	Long	Short	Mid	Long
On+IPRL-IPRB	7	12	16	4.681	3.714	-0.060
On-IPRB	5	1	25	4.830	8.490	-3.007
On-IPRL	19	19	10	1.918	2.786	2.513
On-IPRL+IPRB	14	14	6	3.189	3.347	5.012
On-IPRL-IPRB	1	6	9	9.066	5.410	2.663
On-LM	20	32	14	1.845	-1.001	0.314
RC	28	13	30	0.394	3.420	-4.892
RC+DC	27	9	21	0.533	4.520	-2.199
RC+DC+LM	8	21	26	4.574	2.474	-3.441
RC+DC+VC	9	18	33	4.224	3.047	-6.478
RR	31	34	2	-1.256	-2.369	5.296
RR+LM	3	7	32	5.562	5.288	-6.239
VC	23	31	3	1.517	-0.211	5.221
VC+RR	26	27	19	1.107	0.234	-1.750

¹As compared to the neutral treatment (All Off) at each period.

End

fect on the response variable, yet, in the long-run fell to the 25th spot.

The effects that these two cases produce —particularly the immediate positive effect and future reduction— may shed additional light on why some implemented policies applied in the real world to promote innovation fail to show results beyond the short term. This may even more so be the case due to the fact that some of these treatments may appear quite attractive from a political

stance.

More surprising is the fact that some of the treatments anticipated to produce a positive impact on this (and all) response variables performed quite negatively. Among these is research clustering (RC), which in the short term had virtually no effect above that of the neutral treatment, in the mid run reached 13th and in the long ended as the 30th effect-inducing treatment. The response induced by development clustering (DC) —expected as well to elicit positive effects— also displayed a similar behavior, going up from 18th to 16th and then down to 28th at each respective term. Not even combining these two clustering treatments produced a better response; the treatment RC+DC reached per term the 27th, 9th, and 21st response levels, respectively. Furthermore, when this last treatment was supplemented with either labor mobility (RC+DC+LM) or venture capital (RC+DC+VC), the outcome displayed for each showed a clear downward tendency, making these pass in the short run from 8th and 9th most effect-inducing down to 26th and to 33th in the long term, respectively. The response that these particular treatments generate may appear counter-intuitive to the effect of clustering suggested within mainstream regional planning literature, yet, this may be suggesting that the full impact of research and development clustering may not be felt unless it works in conjunction with a series of elements (in this case the presence of venture capital, labor mobility, royalty sharing rules plus changes to the IPR regime) that go beyond spatial and communication linkage.

Overall, eight of the top-ten treatments with the greater positive response averages in all three time ranges suggest changes to at least one of the IPR parameters (length or breadth). Two examples of this are the pair of treatments with highest response in all time ranges; the top one, suggesting all structural

elements on and a reduction in both IPR parameters (On-IPRL-IPRB), produced a response 9% higher than that of the neutral policy in the short run and a 5.4% and 2.66% positive difference in the mid and long run, respectively. The second, suggesting none of the structural element present and an increment in both IPR parameters (Off+IPRL+IPRB) displayed, on average, a 5.1% larger effect than that produced by the reference treatment in all three terms. Although these two treatments appear as being diametrically opposed, the fact that both propose the above mentioned changes to IPR parameters give more elements to imply that these (IPRs) play an equally —or even more— important role than that of the structural elements considered when it comes to educing higher responses from the model's variables.

The response of this variable to the neutral treatment (All Off) was much more negative than initially estimated, being among the bottom-five in the first two terms and reaching a mediocre 15th rank in the long run. Further, the response this treatment induced was always below that of its alternative (All On), providing more evidence to propose that the null hypotheses earlier presented can be rejected.

To further understand the effects induced by these treatments on the response variable, the results obtained at each time period (5, 10 and 25 years) were contrasted to those obtained for each at year 1 ($2 dt$) to determine the average change in response that each reflected over time. These levels of change were then contrasted with those of the neutral treatment at each period (see table 3.5). This process allows estimating which treatment induces a higher change in response range than that given by the reference treatment over time and, thus, which can be considered more effectual. However, more than contrasting the nominal levels of change (displayed in table 3.4) the importance of

this analysis is based on knowing which of these treatments showed a more noticeable change level over time. In order to fall in this category, a treatment had to display a change in the levels of response above those of the neutral treatment, which showed a 19.89% growth in the short term, and a 36.04% and 26.4% in the mid and long terms, respectively.⁵¹ Although these levels appear to be somewhat significant, when compared to the behavior of the rest of the treatments, these can be considered quite average. A clear case to support this statement is the fact that the nearly twenty percent growth in response shown in the short run by the neutral treatment was only above that of 15 treatments. In the other two terms, the change in the effects of the neutral treatment were also quite ordinary, being above those of 13 other treatments in the mid term and 21 in the long run.

The most significant change in response in the short term was that of no structural elements plus a reduction in both IPR parameters (Off-IPRL-IPRB), which increased 32.3% over a period of five years, a 62.2% above that reflected by the neutral treatment. The second and third larger changes in this time-span were those displayed by the treatments proposing no structural elements and a reduction in IPR breadth (Off-IPRB), which displayed 49.5% more growth than that of the reference, and that suggesting both clustering of research and development (RC+DC), which had 47.6% above the mark. It then becomes easy to see why some of these treatments are selected as policies in the short run (like proposing clustering between research institutions and development industries or a reduction in the property rights schemes) instead of developing new incentives for invention or to allure private capital into these areas.

⁵¹These growth figures represent the change in the response of the response variable from a level of 2.644 in year 1 to levels of 3.270, 3.597, and 3.342 for each of the three time ranges, respectively. Other treatments might display lower change averages, yet might have higher nominal levels of response than those of the neutral policy.

Table 3.5: Effect of Selected Treatments on “New Development” Response Variable: Percentage Change per Period and Comparison to Neutral Treatment

Treatment	Response					
	Short		Mid		Long	
	%Change	Neutral	%Change	Neutral	%Change	Neutral
ALL Off	19.89	0.00	36.04	0.00	26.40	0.00
ALL On	14.65	-26.34	26.15	-27.43	15.26	-42.20
DC	23.60	18.65	41.94	16.36	22.50	-14.76
LM	25.28	27.09	46.58	29.25	41.87	58.63
Off+IPRB	22.42	12.71	39.78	10.39	20.84	-21.03
Off+IPRL	17.03	-14.39	30.08	-16.53	14.38	-45.52
Off+IPRL+IPRB	20.47	2.93	36.89	2.37	24.99	-5.31
Off+IPRL-IPRB	28.81	44.86	51.03	41.59	25.67	-2.75
Off+IPRL-IPRB+LM	20.81	4.64	37.25	3.35	22.65	-14.20

Continued ...

Table 3.5: (continued)

Treatment	Response					
	Short		Mid		Long	
	%Change	Neutral	%Change	Neutral	%Change	Neutral
Off+IPRL-IPRB+RC	20.81	4.64	37.12	3.01	21.34	-19.15
Off+IPRL-IPRB+RC+LM	22.89	15.10	40.92	13.55	24.41	-7.52
Off-IPRB	29.73	49.48	52.40	45.41	23.80	-9.85
Off-IPRL	18.00	-9.49	33.25	-7.75	30.57	15.81
Off-IPRL+IPRB	12.87	-35.32	23.64	-34.41	20.55	-22.14
Off-IPRL-IPRB	32.27	62.22	57.19	58.68	29.20	10.64
Off-IPRL-IPRB+LM	24.26	21.95	44.55	23.60	38.53	45.99
Off-IPRL-IPRB+RC	27.08	36.13	49.55	37.50	41.20	56.08
On+IPRB	23.62	18.76	42.08	16.75	23.62	-10.51
On+IPRL	18.21	-8.47	32.99	-8.46	24.20	-8.33
On+IPRL+IPRB	25.12	26.28	45.28	25.64	30.86	16.90
Continued ...						

Table 3.5: (continued)

Treatment	Response					
	Short		Mid		Long	
	%Change	Neutral	%Change	Neutral	%Change	Neutral
On+IPRL-IPRB	18.80	-5.51	33.55	-6.90	19.57	-25.86
On-IPRB	29.21	46.87	51.74	43.56	26.04	-1.35
On-IPRL	21.59	8.52	39.14	8.59	28.93	9.61
On-IPRL+IPRB	19.89	-0.01	36.25	0.57	28.63	8.45
On-IPRL-IPRB	14.24	-28.41	25.28	-29.85	13.37	-49.36
On-LM	14.58	-26.72	26.38	-26.81	18.98	-28.11
RC	27.61	38.79	49.16	36.40	27.44	3.98
RC+DC	29.36	47.60	52.60	45.96	32.67	23.77
RC+DC+LM	17.16	-13.75	30.27	-16.02	14.05	-46.79
RD+RD+VC	19.40	-2.46	33.96	-5.78	12.95	-50.92
RR	16.43	-17.38	30.63	-15.02	30.90	17.05
Continued ...						

Table 3.5: (continued)

Treatment	Response					
	Short		Mid		Long	
	%Change	Neutral	%Change	Neutral	%Change	Neutral
RR+LM	21.40	7.59	37.40	3.76	13.68	-48.17
VC	15.82	-20.49	29.18	-19.04	26.55	0.60
VC+RR	18.61	-6.42	33.43	-7.25	21.52	-18.49
End						

On the other hand, among the treatments with the lowest change range in this time bracket was that suggesting no structural changes plus a reduction in the IPR length and an increase in their breadth (Off-IPRL+IPRB), which increased 12.87% in five years, representing 35.32% less than that of the neutral treatment. Other treatments with slower changes as compared to the base treatment were On-IPRL-IPRB (14.24% change and 28.4% less than the norm) and On-LM (with 14.58% change being -26.72% below the mark). Then again, although the policy suggesting all structural elements on plus a reduction in IPR parameters (On-IPRL-IPRB) ranked as the most effective in terms of response, it had a lower change degree than that of the neutral treatment, making it fall below it in this type of analysis. This can also help explain why such an elaborate policy—requiring the presence of multiple structural elements and changes to the current IPR regime—might elicit a less evident change in the short run.

The treatments with the largest change rates in the short run displayed some consistency in the mid run. Again, Off-IPRL-IPRB showed changes at levels above those of the reference variable. Here, the degree of growth shown by these results revolved around the 57% level, meaning that these had a growth in response close to 60% above that of the neutral treatment. Just as the top response-inducing treatments, the least effective also showed some consistency, being in this list the two of the previously mentioned (Off-IPRL+IPRB and On-LM), along with All On which produced effects 27.4% less than the norm. The negative growth those treatments below the norm reflected ranged from 34.6% (that of Off-IPRL+IPRB) to 5.7% (produced by RC+DC+VC) below par. However, it needs to be stated that the actual change range these treatments showed, although less than that of “All Off,” was by no means small; for example, the treatment suggesting all structural elements on plus a reduction in the IPR

length and breadth (On-IPRL-IPRB), which displayed one of the largest negative growths in this term (29.8%), actually had a 25.28% change with respect to its level at year 1. Yet, that seems to be not good enough when compared to that of the above mentioned treatment suggesting no structural change and the same reduction in IPR levels (Off-IPRL-IPRB), which growth from year 1 to year 10 is estimated to be nearly 58%. From this approach it becomes more evident that even those policies showing levels of change below those of the reference treatment in fact are displaying positive changes over time. None of the treatments analyzed at any time period showed a growth level below 14%, let alone a negative one.

Analyzing the treatment's behavior in the long run brought to the picture other treatments not previously ranked at the top. Here, the effect response variables had above research clustering as a treatment reached more than 42% (case of Off-IPRL-IPRB+RC). This growth would entail a 56% above that of the neutral treatment. Other treatments that displayed a substantial growth are Off-IPRL-IPRB+LM (38.5%), and LM (41.2%), each 46% and 58.6% above the neutral treatment's level. Among the least effective treatments is again that suggesting all structural changes on plus a reduction in both IPR parameters (On-IPRL-IPRB), which showed a change of nearly 50% below the reference level. Others at the bottom of this list are the two combinations of clustering plus labor mobility (RC+DC+LM) and venture capital (RC+DC+VC), which respectively produced growths 46.8% and 50.9% below the standard. This behavior once again concurs with the notion that policies suggesting clustering may result counterproductive if not applied with other structural and parametrical changes.

Lastly, ranking and assigning the effects of each of these treatments to one of three categories describing their status as policies (best, moderate, or unsatisfac-

tory), based on their overall performance in all three periods, closes the analysis of the general model. (see table 3.6).

Here, ten treatments ranked as best policies when compared to their change over time and to that of the neutral treatment (which ranked among the least effective, as later explained). Within the top-tier the treatment proposing all structural elements on plus a reduction in IPR levels (On-IPRL-IPRB) proved to be the most positive in both consistency and performance. As pointed out earlier, the second most effective treatment proved to be its almost diametrically opposite, suggesting no structural elements and an increase in both IPR length and breadth (Off+IPRL+IPRB). Of the following eight treatments only two more suggested all structural changes present, being the third most effective that suggesting all structural treatments on (All On).

A combination of changes to IPR parameters appear in eight of the ten top policies, again giving more weight to these parametric elements than originally expected. Examples of these treatments are those treatments recommending all structural changes on (or off), plus an increase in IPR length and a reduction in their breadth (On+IPRL-IPRB and Off+IPRL-IPRB, respectively), and all structural changes off, with the exception of research clustering, an increase in IPR length and a reduction of their breadth (Off+IPRL-IPRB+RC), which shares the 7th spot with the treatment suggesting a combination of research clustering and labor mobility (RR+LM).

The previous analysis showed venture capital as producing a response above that of the neutral treatment in all terms with the only exception of the mid-run, and was the only structural element that, operating individually as treatment, produced the highest response. Venture capital as policy combined with the two treatments promoting sector clustering also ranked among the mod-

Table 3.6: **Response to Treatment: Overall Rank**

	Treatment	Rank¹
	On-IPRL-IPRB	1
	Off+IPRL+IPRB	2
	All On	3
B	On+IPRL-IPRB	4
E	On-IPRL+IPRB	5
S	Off-IPRL+IPRB	6
T	Off+IPRL-IPRB+RC	7
	RR+LM	7
	Off+IPRL	9
	Off+IPRB	10
	On-IPRB	11
M	RC+DC+LM	12
O	Off-IPRL	13
D	VC	14
E	On+IPRL+IPRB	15
R	On-IPRL	16
A	RC+DC+VC	17
T	Off+IPRL-IPRB	17
E	On-LM	19
	Off+IPRL-IPRB+RC+LM	20
U	Off-IPRB	21
N	Off-IPRL-IPRB	22
S	RR	23
A	DC	24
T	Off+IPRL-IPRB+LM	25
I	VC+RR	26
S	RC+DC	27
F	On+IPRB	28
A	LM	29
C	All Off	30
T	Off-IPRL-IPRB+LM	31
O	On+IPRL	32
R	RC	33
Y	Off-IPRL-IPRB+RC	34

¹Based on overall performance ranking.

erate effect-inducing treatments, reaching, along with the policy proposing no structural elements, a reduction in IPR length plus a reduction in their breath (Off+IPRL-IPRB), the 17th spot. It is important to point out that the effects these treatments display are not necessarily additive, in fact, the response that each resulting combination of treatments may end up producing on the response variable is quite unpredictable; a clear example of this is that of the top performing treatment combined with the unsatisfactory research clustering (33th), which resulted in the bottom treatment (Off-IPRL-IPRB+RC). The neutral treatment (All Off) ranked as the 30th with respect to both performance and consistency, ranking within the bottom group and, thus, considered unsatisfactory.

Overall, 15 of the 22 treatments proposing changes to the IPR parametric factors concentrated in both the best and moderate ranks, being all but two those within the highest echelon (as opposed to 7 within the 13 at the bottom division). Therefore, the model indicates that —on average— altering the rules of intellectual property rights produces a higher response from particular variables than a combination of structural elements does. Furthermore, these findings could further assist rejecting the hypothesis that various treatments — composed from five structural elements as well as specific changes to two parametric variables— do not induce a response in specific variables larger than that induced by a particular ‘neutral’ treatment. Yet, the effects of these changes in the levels of new innovation and other selected response variables when the model’s initial conditions are set to reflect those of each of the two countries under scrutiny will provide further data to estimate the degree and sign of these, as well as to corroborate if some of these indeed encourage larger effects than the reference policy. The analysis of these results for each of the adapted models is presented in the following section.

3.3.2 Adapted Model for Spain

In addition to setting all of the general model's structural elements to the "All On" treatment position the process to simulate the performance of Spain's MBTS requires that the value of some of its components—or initial conditions—be also adjusted. This procedure allows the model to "mimic" more closely the initial levels expressed by particular areas within the system's reality before its performance assessment begins. The model's initial conditions for Spain's representation are: interest rate at 3%; tax rate at 35%; price of knowledge units, 100; labor hand levels at 18,000, with a level of 1,000 entering the sector per cycle (with a research-to-development ratio of 3:1); level of existing research infrastructure at 400 million (requiring 10,000 units per research worker per cycle); level of existing infrastructure for development at 180 million (requiring 2,000 units per development worker per cycle); government endowment to R&D at 507 million; net financial resources to research and net financial resources to development, 0; venture capital funds 120 million; international venture capital available at 100 million (with 100,000 entering the fund each cycle and 1% of the total fund going to investment, when the model suggests availability); savings and spendings both at 0; patents at 200; public knowledge at 1,000; IPR length at 25 years and breadth at 50%; the levels of natural resources and genetic resources at 10 million; biosafety at 10 million, with an inspection level of 100,000; and health safety all at 10 million, with an inspection level of 200,000; and new research and new development set both to a level of 1 to avoid divisions by zero.⁵² More specifically, these conditions are introduced by setting the initial rates and levels of particular flows and stocks at amounts that emulate the de-

⁵²The levels for variables that defer from those of the non-parametric model were obtained from three main sources: Relevance of Biotechnology in Spain 2009 (Genóma España, 2009); OECD Biotechnology Statistics 2009 (van Beuzekom and Arundel, 2009); and *Informe Anual 2009* (ASEBIO, 2010).

gree currently displayed by the actual segments within Spain's MBTS that these specific sections of the model are designed to represent. Further, these are expressed in terms of the model's inputs, outputs, and nomenclature. Moreover, the degree at which these parameters are set also respects the general model's proportions allowing its transformed version to maintain the rest of its original initial conditions and —most important— its functionality. However, although more initial conditions were available and could have been introduced into the general model's portrayal of Spain's MBTS, the number of these had to agree with those of variables that could be identified for the case when the general model is set to describe Mexico's system. This restriction derives from the limited available data on the sector in the latter country. The agreement in the number of adjusted initial conditions between model versions is also essential to provide more validity to the response comparison process presented later in the study.

As previously mentioned, the overall performance of the model⁵³ is assessed based on the response of 15 selected variables to the treatment representing Spain ("All On" plus initial conditions). The response expressed by these is evaluated using a similar methodology to the one used in the previous section to estimate the effects of multiple treatments on specific variables. Here, the response for each variable is obtained by: 1) running the altered model 100 times and recording and analyzing their behavior (results) at each time period; 2) the mean for each time period of simulation (meaning the arithmetic mean of 100 observations per dt) is obtained and used to define a single general observation per dt for each response variable; and 3) these points are then used as input to run a time series regression that helps obtain the specific trend line that de-

⁵³In this and forthcoming sections, the general model's adapted version for Spain is equally referred to as treatment, adapted model (or simply as model), or policy. This also applies for the case when the general model is set to represent Mexico's MBTS.

scribes the effects of the treatment on the response variable over time (see table 3.7).⁵⁴ Using these trend lines the projected behavior of all response variables in the short (5 years), mid (10 years), and long (25 years) terms can then be estimated. Depending on the variable, each response is measured either in: a) "knowledge units," which are the result of all research or development activities (case of *New Research*, *Research Potential*, *New Development*, *Development Potential*, *To Market*, *Patented Knowledge*, and *Open Access Knowledge*); b) "knowledge currency" which are knowledge units multiplied by price (*Government Income*, *VC to Research*, and *VC to Development*); or c) "human capital units" defined by the value of a single human capital element expressed in knowledge currency terms (*Research Infrastructure Cap.* and *Development Infrastructure Cap.*). The level of *Genetic Resources* is also measured in "knowledge units" due to the fact that the level of these varies with respect to research's success rate (which is measured in these units). Lastly, both *Biosafety* and *Health Safety* are measured in "knowledge currency" since the levels of these depend on those of their particular funds given in these units. The results of this simulation are found both in table 3.7 and 3.8.

The results obtained from this simulation⁵⁵ suggest that the variables *To Mar-*

⁵⁴Also using MINITAB the fitted trend lines were set to be S-Curve (Pearl-Reed Logistic) of the form:

$$Y_t = (10^a) / (\beta_0 + \beta_1 \cdot (\beta_2)^t)$$

or quadratic trend model of the form:

$$Y_t = \beta_0 + \beta_1 \cdot t + (\beta_2 \cdot t^2) + e_t$$

depending on the better-fit information provided by the statistical Measures of Accuracy. In cases when a Pearl-Reed Logistic trend line model is used the asymptote was also considered as relevant parameter.

⁵⁵Variations are estimated by comparing each variable's response at a particular term—as obtained with the use of each variable's trend line equation—with those obtained for the initial term. For example: if a variable displayed an initial response value (at $t = 1$) of 25 and one of 50 in the mid term ($t = 10$), its variation in response in the mid term will be of 100%. Variations for the short term are calculated by contrasting the variable's response at $t = 1$ (initial value) with

Table 3.7: Adapted Model for Spain: Parameters for Selected Variables

Response Variable	Equation Parameters							
	MAPE	MAD	MSD	Asymptote	10^a	β_0	β_1	β_2
New Research	17.5821	0.6688	0.9446	5.4188	100	18.4541	37.8943	0.8754
Research Potential	1.6986	0.3303	0.3158	0.3303	100	4.1442	1.2171	0.9686
New Development	16.3001	0.6551	0.7554	5.8658	100	17.0479	31.1214	0.8841
Development Potential	1.6215	0.2887	0.1977	21.5964	100	4.6304	1.4540	0.9587
To Market	34.9969	0.2834	0.1330	1.3531	10	7.3906	42.1630	0.9006
Patented Knowledge	0.3151	0.4846	0.4109	614.8350	1000	1.6265	3.3719	1.0157
Open Access Knowledge ^a	9.7470	0.4883	0.3929	9.0561	100	11.0423	16.6231	0.9615
Research Infrastructure ^a	0.0475	0.0041	0.0001	9.2701	100	10.7874	0.9316	0.9758
Development Infrastructure ^a	0.0620	0.0051	0.0004	8.0953	100	12.3529	-0.2790	0.9458
Government Income ^a	0.1025	0.0089	0.0002	8.6592	100	11.5485	-0.0002	1.1174
VC to Research ^{b,c}	54.5000	29.3000	2038.0000	-	-	31.3000	-5.3200	0.1453

Continued ...

Table 3.7: (continued)

Response Variable	Equation Parameters									
	MAPE	MAD	MSD	Asymptote	10 ^a	β_0	β_1	β_2		
VC to Development ^b	17.3000	206.2000	83364.7000	2020.4500	10000	4.9494	8.6570	0.9394		
Genetic Resources ^a	0.0010	0.0001	0.0000	7.0007	100	14.2843	0.0011	1.0444		
Biosafety ^a	0.6647	0.0484	0.0031	6.3181	100	15.8276	-1.3269	1.0167		
Health Safety ^a	0.2438	0.0173	0.0004	6.9617	100	14.3642	-0.0348	1.0603		

^aData converted using Log 10

^bData converted using square root

^cThe parameters for this variable were estimated using a quadratic trend line model.

End

ket, *New Research*, *New Development*, and *VC to Development* display a consistent growth tendency throughout terms. Overall, *To Market* displayed the steepest change showing an 87.42% growth in the short term, 230.4% in the mid, and 446.12% in the long run. This change suggested an increase of 0.45 products going to the market to 1.31 in the long term⁵⁶ This variable's response shows that the system—as modeled—is being successful at creating new marketable products derived from biotech.

Both *New Research* and *New Development* displayed constant growth allowing their response level to nearly triplicate in the long run, reaching levels of 5.40 and 5.84, a 156.67% and 141.75% growth from its initial value, respectively. The response of these variables captures the system's actual new information and new products or services production proficiency (the system's potential in these two areas is addressed later).

The degree of venture capital going to development showed a positive expansion of 31.36% in the short term, reaching 1,043 units; a 64.43% in the mid to 1,345.79; and a 136% in the long term for a level of 1,876.14, reflecting the constant flow of these resources into the system. This response suggests that the avenues designed to promote the access to such funds—as defined by the model—operate successfully.

Finally, venture capital to research—which for the initial two terms showed a pronounced negative change—displayed the highest variation in response of any variable in the long term, increasing from -16.98 to 128.55, a 505.19% from its initial value. In the model the behavior of this last variable concurs with Arrow's proposition that investment in basic scientific activity is risky due to

that at $t = 5$ (short term value).

⁵⁶It is key to mention that the response of this variable as defined by the time series regression expresses an averaged output and not a concrete number of products reaching the market per cycle (as the model does). This average, however, properly reflects the system's innovation creation capacity as well as its direction.

Table 3.8: Adapted Model for Spain: Response from Selected Variables

Response Variable	Response						
	Initial	Short	%Change	Mid	%Change	Long	%Change
New Research (knowledge)	2.11	3.51	66.83	4.74	125.09	5.40	156.67
Research Potential	18.92	19.88	5.11	20.89	10.42	22.77	20.38
New Development (innovation)	2.42	3.83	58.36	5.08	110.06	5.84	141.75
Development Potential	16.76	17.91	6.85	19.03	13.52	20.80	24.13
To Market	0.24	0.45	87.42	0.79	230.45	1.31	446.12
Patented Knowledge	195.88	179.63	-8.30	160.47	-18.08	111.39	-43.14
Open Access Knowledge	3.79	4.49	18.59	5.37	41.78	7.47	97.38
Research Infrastructure Cap.	8.57	8.68	1.37	8.80	2.79	9.04	5.55
Development Infrastructure Cap.	8.26	8.20	-0.74	8.16	-1.29	8.11	-1.88
Government Income	8.66	8.66	0.00	8.66	0.01	8.70	0.44
VC to Research	21.24	-7.37	-134.70	-16.98	-179.94	128.55	505.19

Continued ...

Table 3.8: (continued)

Response Variable	Response							
	Initial	Short	%Change	Mid	%Change	Long	%Change	
VC to Development	794.31	1043.41	31.36	1345.79	69.43	1876.14	136.20	
Genetic Resources	7.00	7.00	0.00	7.00	-0.01	7.00	-0.06	
Biosafety	6.92	7.01	1.37	7.15	3.42	7.82	13.08	
Health Safety	6.98	6.99	0.16	7.02	0.51	7.29	4.45	
End								

the fact that outputs (or their value) cannot be predicted perfectly from inputs; reason why there is virtually no growth in this variable's response in the short and mid terms. This also agrees with the notion that private profit-maximizing entities initially discriminate against investing in such research-intensive processes until these can efficiently shift such risks away from them. The model captures a reduction of these risks, as more marketable products become available, which happens when *To Market* expresses growth, increasing investor's trust and ultimately inciting more venture capital investment in basic research.

Conversely, five variables —*Government Income*, *Patented Knowledge*, *Research Infrastructure Cap.*, and *Development Infrastructure Cap.*, as well as *VC to Research* in the first two terms— compose the set of those with the least response variation in all periods. From these, the variable defining patented knowledge showed the most negative change; going from a 179.63 in the short, to 160.47 in the mid and finally down to 111.39 in the long run. This tendency represents an initial 8.3% reduction followed by an 18.08% decrease in the mid and a final contraction of 43.14% in the long. The behavior of this variable's response as determined by the model may derive from the fact that, as more information becomes privatized and more difficult to access (due to licensing costs), the success of basic research becomes less probable. Therefore, suggesting that successful research —although desirable— might have a negative impact on the overall volume of patent filings.

In general, the variation expressed by government resources remained below 1% throughout all three periods (0.0%, 0.01%, and 0.44%, respectively). However, the model also takes into account that most of government's income allotted to R&D every period is fixed (generally as a fraction of the GDP). This way, the estimated changes in response determine only variations departing

from such fixed funds level. Further, since government resources in the model are expressed in large "knowledge currency" amounts (and the results here presented have been transformed using *Log10*), these changes —when available— can be considered significant.⁵⁷

Although marginal (always less than 2%), the negative response change in development's infrastructure capacity may also be associated to patented knowledge's behavior. This tendency may suggest that a reduction in the volume of patents over time could come along with a private sector's investment reduction in infrastructure; as the development industry finds it more difficult to appropriate knowledge, less resources are allocated to expand the infrastructure where innovations are produced. Nevertheless, the change is so small that it does not seem to affect neither the system's overall development potential nor its capacity to produce marketable products.⁵⁸ Research's infrastructure capacity, on the other hand, shows growth in all three terms; 1.37% in the short (from 8.57 to 8.68), 2.79% in the mid (8.68 to 8.80), and 5.55% in the long (from 8.80 to 9.04). Although small, this positive tendency captures the effects of government's investment in basic research. Being government's investment the main source of funding for research infrastructure, this marginal-yet-positive increment may be due to the expansion of government resources over time.

Concluding this segment, *VC to Research's* negative response change in the first two terms, going from an initial 21.24 to -7.37, and further down to -16.98 (a -134.70% and -179.94% reduction, respectively) may be a consequence of investor's inability to shift risks away from them in the short and mid terms, as

⁵⁷For example, a change in response of 0.01%, going from 8.66 to 8.70 is in fact a change of approximately 43 million, in real terms. This is due to the fact that 8.66 transformed into real numbers is over 457 million, while 8.7 is slightly over 501 million.

⁵⁸So as *Government Income*, it is useful keeping in mind that this variable's response is also provided in *Log10* terms. This meaning that, although its levels of change appear small, these are in fact more significant when expressed in non-*Log10* terms.

previously suggested.

The variables *Research Potential* and *Development Potential*, which serve in the model as benchmarks for the system's knowledge discovery capacity and ability to transform new information into marketable products and services, expressed positive response expansions. The former showed a variation of 5.11% in the short, 10.42% in the mid, and 20.38% in the long while the latter displayed a change of 6.85%, 13.52%, and 24.13%, respectively. This behavior suggests that —overall— Spain's MBTS can be considered a healthy system capable of expanding its knowledge discovery as well as of applying new knowledge to create new marketable products and services.

Most of the variables that capture the response of those resources necessary for research and development activities, *Genetic Resources*, *Biosafety*, *Health Safety*, and *Open Access Knowledge*, had —with one exception— a positive behavior. In particular, the level of open access knowledge displayed the most notable growth going from an 18.59% increase in the short, a 41.78% in the mid, to a 97.38% in the long run. Once again, the changes in response displayed here appear to be connected with those of patented knowledge; having a somewhat inverse relation, every time that newly discovered knowledge is determined as non-appropriable within the model, the positive response of this variable tends to increase. Conversely, that of patented knowledge tends to decrease when this happens. Furthermore, as the temporary monopoly provided by patents expires and the once-private information becomes public, the change in response of this variable increases and —unless patents are produced at a rate that compensates for such expiration— the change in the level of patented information becomes affected negatively.

Both biosafety and health safety capture the system's ability to assess the

safety of new products and services before these reach the market. The capacity to conduct these reviews is based on the level of resources that each area has to do so, which level is captured by these variables. The former presented a positive variation, going from 1.37% in the short, 3.43% in the mid, to a 13.08% increase in the long term. The more modest increase shown by health inspection services captured a 0.16% growth in the short, a 0.51% in the mid, and a final 4.45% increment in the long term. What these results express is that, as more marketable products are developed (as suggested by the significant response in change of *To Market*), the demand for these review procedures also expands. Furthermore, as these services are performed, each of these sectors increases its resources which, in time, allow for more (in number) review processes.

Finally, the prime element of all basic research activity in the sector, the level of *Genetic Resources* showed a minor decrease over time. In the short term, however, the model captured no change in the level of these resources. Variations in response, although quite insignificant, were only expressed in the mid and long terms, being these of -0.01% and -0.06%, respectively. These results may suggest that —although basic research is being successfully conducted— the rules for the access and depletion of genetic resources are somewhat effective as captured by the model.

3.3.3 Adapted Model for Mexico

Assessing the model's adapted version for Mexico requires setting all of its structural elements to the "All Off" treatment position as well as adjusting the initial conditions necessary to further emulate the country's MBTS behavior. These initial conditions for Mexico are: interest rate at 3%; tax rate at 35%; price per knowledge unit 100 (one "knowledge currency" token equals 100 "knowl-

edge units”); sector’s labor hand at 14,500, with a level of 1,000 entering the sector per cycle and a research-to-development ratio of 1:5; level of existing research infrastructure at 90 million (with 5,000 units per research worker every cycle); level of existing infrastructure for development at 32 million (requiring 2,000 units per development worker per cycle); government endowment to R&D at 430 million; net financial resources to research and net financial resources to development, 0; venture capital funds, 0; savings and spendings, 0; patents at 186; public knowledge at 1,000; IPR length at 25 years and breadth at 50%; the levels of natural resources and genetic resources at 10 million; biosafety at 10 million, with an inspection level of 100,000; and health safety all at 10 million, with an inspection level of 200,000 (equal to Spain to suggest an “international standard”); and new research and new development set both to a level of 1 to avoid divisions by zero.⁵⁹ As suggested, the number of these conditions

⁵⁹These figures were either obtained or calculated using data produced by the National Institute of Statistics and Geography, INEGI and by the Mexican Academy of Sciences, AMC. Mexico’s human resources in S&T are calculated using two tables developed by INEGI: *Recursos humanos: Población que completó exitosamente el nivel de educación ISCED 5 o superior y está ocupada en actividades de ciencia y tecnología, por nivel de educación y campo de la ciencia según ocupación, 2008* and *Recursos humanos: Miembros del sistema nacional de investigadores según área de conocimiento, 1991-2010* (INEGI, 2008, 2011). More specifically, by adding the totals for *ciencias naturales y exactas* (200,681), *ingeniería y tecnología* (629,833), *ciencias de la salud* (502,389), and *ciencias agropecuarias* (111,972) presented in the first table, a total of 1,444,875 is obtained as Mexico’s available human resources in S&T. Determining that biotech accounts for about 1% of all S&T human resources, the figure for the sector comes to be somewhere near 14,500. Then, by adding the totals for *biotecnología y ciencias agropecuarias* (1,711) plus a fraction (10%) of *Biología y Química* (244) and *Medicina y Ciencias de la Salud* (144), found in the second table’s data, an approximation to the total number of researchers in biotech or areas related can be calculated for the year 2008. This sum allows estimating a total of 2,100 as the number of researchers in biotech and 12,400 as those engaged in development activities in this area. According to a study on the state of biotech in Mexico developed in 2010 by the AMC, there are nearly 45 mayor research centers in the country (including professional associations, like the SBMM). Determining that each can allocate 2 million in resources for human capital, the total infrastructure for human capital in basic research in Mexico is estimated at 90 million (a capacity of 18,000). For development, the same source suggests that approximately 375 industries are engaged in producing these technologies locally. Determining for these a budget for human capital of 85,000 for each, total infrastructure for human capital in development can then be estimated at 32 million (a capacity of 16,000). The difference in costs in human capital personnel (5,000 for those in research and 2,000 for those in development) are introduced in the model to capture the higher sophistication (facilities, labs, and other research instruments) that research infrastructure requires to accommodate its hu-

agrees with that of those used for modeling Spain. The results of this simulation are found in tables 3.9 and 3.10.

The model's simulation shows three variables, *New Research*, *New Development*, and *To Market* as having the largest positive response variations throughout all three periods. In particular, the response of *New Research* displays a 17.77% growth in the short term and a 32.91% in mid, going from producing 3.55 new projects to 4.72. Although still increasing, the long run change with respect to its initial level was only 31.17%, closing at an estimated capacity of 4.66 successful projects. These results present a system healthy enough to generate new research near or above the levels displayed by the adapted model for Spain. The variable *New Development*, on the other hand, expressed a 48.49% and a 88.02% response increase in the short and mid terms, respectively, and a significantly higher 111.65% growth in the long run. The model suggests the system boosts the production of new developments with market potential almost twofold from an initial 2.59 up to 5.48 in the long run.

The widest and steepest change rate, however, was displayed by *To Market*. This variable's response increased 24.8% in the short, 60.73% in the mid, and achieved a 184.34% increment in the long run, the most significant of all assessed variables for this model in all terms. Although this variable's response is somewhat similar in every term to that displayed in the Spain's model, the overall growth showed here is less abrupt, especially in the last two terms. This difference may be a result of the absence in this model of structural elements aiming at promoting the creation of more marketable products (venture capital investment in both R&D, clustering, labor mobility, etc.) otherwise available in

man capital. Development work force, on the other hand, requires less resources as it focuses more on the sector's managerial and production activities. Therefore, such resources are mostly aimed at salaries and other types of compensation. Finally, the same AMC study estimates the number of patents associated to modern biotech in Mexico at around 186 (AMC, 2010).

Table 3.9: Adapted Model for Mexico: Parameters for Selected Variables

Response Variable	Equation Parameters									
	MAPE	MAD	MSD	Asymptote	10 ^a	β_0	β_1	β_2		
New Research ^a	21.7660	0.5559	0.6518	-	-	3.3650	0.0956	-0.0014		
Research Potential	1.9813	0.3533	0.4577	21.5726	100	4.6355	1.2321	0.9352		
New Development	15.1096	0.6182	0.6941	5.4950	100	18.1985	26.0025	0.8869		
Development Potential	1.2005	0.2013	0.1137	18.4507	100	5.4199	1.1500	0.8924		
To Market	35.5523	0.2788	0.1111	2.0002	10	4.9995	19.5328	0.9641		
Patented Knowledge	0.3990	0.5802	0.6435	299.1090	1000	3.3433	2.0912	1.0227		
Open Access Knowledge ^b	7.6385	0.3445	0.2163	6.2786	100	15.9270	15.0257	0.9238		
Research Infrastructure ^b	0.1554	0.0129	0.0004	9.0135	100	11.0944	1.6975	0.9503		
Development Infrastructure ^{a,b}	0.1081	0.0081	0.0001	-	-	7.4918	-0.0028	0.0001		
Government Income ^b	0.0496	0.0043	0.0000	8.6073	100	11.6181	0.0000	1.2429		
VC to Research	-	-	-	-	-	-	-	-		

Continued ...

Table 3.9: (continued)

Response Variable	Equation Parameters							
	MAPE	MAD	MSD	Asymptote	10 ^a	β_0	β_1	β_2
VC to Development	-	-	-	-	-	-	-	-
Genetic Resources ^b	0.0006	0.0000	0.0000	7.0009	100	14.2838	0.0016	1.0413
Biosafety ^b	0.2716	0.0196	0.0005	3.7824	100	20.4152	-6.0214	1.0030
Health Safety ^b	0.0876	0.0062	0.0001	6.9730	100	14.3410	-0.0355	1.0355

^aThe parameters for this variable were estimated using a quadratic trend line model

^bData converted using Log 10.

End

Table 3.10: Adapted Model for Mexico: Response
from Selected Variables

Response Variable	Response							
	Initial	Short	%Change	Mid	%Change	Long	%Change	
New Research	3.55	4.18	17.77	4.72	32.91	4.66	31.17	
Research Potential	17.50	18.99	8.49	20.17	15.23	21.37	22.11	
New Development	2.59	3.84	48.49	4.86	88.02	5.48	111.65	
Development Potential	15.78	17.28	9.46	18.06	14.41	18.44	16.81	
To Market	0.43	0.54	24.80	0.69	60.73	1.23	184.34	
Patented Knowledge	180.82	167.80	-7.20	151.15	-16.41	102.55	-43.29	
Open Access Knowledge	3.48	4.40	26.50	5.26	51.28	6.17	77.33	
Research Infrastructure	7.92	8.26	4.24	8.54	7.87	8.91	12.47	
Development Infrastructure	7.49	7.47	-0.24	7.45	-0.42	7.47	-0.15	
Government Income	8.61	8.61	0.00	8.61	0.00	8.63	0.23	
VC to Research	-	-	-	-	-	-	-	

Continued ...

Table 3.10: (continued)

Response Variable	Response							
	Initial	Short	%Change	Mid	%Change	Long	%Change	
VC to Development	-	-	-	-	-	-	-	
Genetic Resources	7.00	7.00	0.00	7.00	-0.01	7.00	-0.07	
Biosafety	6.97	7.04	1.04	7.13	2.42	7.46	7.06	
Health Safety	6.99	7.00	0.09	7.01	0.23	7.07	1.17	
End								

the model's version for Spain.

The variables expressing less response in this model were *Patented Knowledge*, *Development Infrastructure Cap.*, *Research Infrastructure Cap.*, and *Government Income*. The level of patents followed a decreasing tendency almost identical to that assessed in the model for Spain. In this case the number of patents decreased from an initial level of approximately 180 down to 102 in the long term, an overall 43.29% reduction. This similarity in behavior may also find explanation in the "privatizing information" effect suggested in the previous section to support this variable's behavior in the model representing Spain.

Although among those variables with negative response, the minimal change displayed by *Development Infrastructure Cap.* (less than 1% in all terms) allowed it to maintain, on average, a level of 7.47 throughout all terms. Such marginal fluctuation may be associated to less private investment in development activities locally, as captured by the absence of venture capital to development in this model's version, ultimately impacting investment in infrastructure. The reduction of available patents over time could also be helping induce such negative effects. Conversely, *Research Infrastructure Cap.* showed limited but positive growth in all three terms (4.24%, 7.87%, and 12.47%, respectively), going from 7.92 up to 8.91 in the long run. This variation displays the effectiveness of local funding as captured by the model. Lastly, *Government Income* expresses no growth in the short and mid terms, and only a minor 0.23% increase for the long run, change that represents an increase of slightly over 19 million units when expressed in real numbers. Then again, government resources to R&D in the model are fixed every term, therefore, any surplus going into these suggests the government benefits from the system's current structure.

The overall model's potential, as captured by the response of the variables

Research Potential and *Development Potential*, also presents Mexico's system as capable of both discovering new knowledge and producing marketable innovations. In particular, the system's research inherent capacity suggests an overall 22.11% growth over the total time period analyzed, going from an initial 17.5 capacity up to a 21.37. The system's ability to innovate also shows a steady growth, expanding from 15.78 to 18.44 in the long run, a total 16.81% increase. These results suggest the system's potential—as modeled—does not seem to be as ineffectual as initially estimated. However, both research and development's real capacity is ultimately determined by the output of marketable products, as measured by *To Market's* response, reviewed later in this section.

The behavior of the variables measuring the resources necessary for R&D biotech processes is also quite analogous to that displayed by the model's counterpart for Spain. Here the level of *Genetic Resources* remains unchanged in the short term and marginally altered in the mid and long terms (-0.01% and -0.07%, respectively). This echoing behavior, however, may be due to the fact that both models are set at the same initial value and access rate for genetic resources. Yet, by keeping these parameters equal in both models, this variable's response can help determine which genetic resources are more sensible. Therefore, exposing the need for more substantial rules to control access to these. Based on this, it can be inferred that in this model's version the access to these resources is less protected.

The response provided by *Biosafety* shows a moderate 1.04% and 2.42% increase in the short and mid terms, respectively, and an overall 7.06% in the long run, promoting a variation from an initial 6.97 level to a final 7.46. Likewise, *Health Safety's* response in both initial terms was positive (0.09% and 0.23%, respectively), while the level and overall long-term change was considerably

below that of biosafety, varying only 1.17% from an initial 6.99 to a 7.07. This shows the positive impact that regulations aiming at reducing risks have on the creation of new services (both biosafety and health inspection services are represented as private enterprises in the model). The behavior of these variables, as it happens in the alternative model for Spain, may be due to the fact that as more marketable products emerge, more biosafety and health inspection reviews are required and more growth is induced to both sectors.

Lastly, *Open Access Knowledge* presents the most salient expansion in this model, going from an initial 3.48 level up to a final 6.17 in the long run, an overall 77.33% increment. As suggested previously, this variable's response displays an inverse relation with that of patented knowledge. In this particular case, it presents constant increments with respect to its initial level in all terms, 26.5%, 51.28%, and the above mentioned 77.33%, respectively. Although these changes are all considerable, the overall variation is less abrupt than that produced by the model for Spain. This can be due to the fact that, although the fundamentals of IPR regulation are the same in both models, the absence of mechanisms aiming at establishing more "open information" environments (such as clustering and collaborative projects promoted throughout Europe and captured by the model's version for Spain) in Mexico are impeding the system from reaping the full benefits of open access information.

Model Validation

Establishing if the behavior of these models reasonably reflects that of the systems operating in both countries requires reviewing the data produced by these in more detail. Yet, since the initial values for most of the variables assessed by these models had to be calculated through the merger of multiple sources

of data or through other estimation procedures, validating the results that each produced for every variable through direct contrast with official systematically produced data (time-series) is an unattainable task. However, formal information for modern biotech patents is (partially) available in such form for both countries and can be used to contrast the behavior of the outcome of the key variable *Patentable Knowledge* produced by both models with real data. By bringing together facts on how research and development efforts successfully consolidate into transferable information, this pivotal variable can be used to substantially validate the results of both models through direct contrast with existing data and thus, used to provide more robustness to this study.

To assess if the information for patents produced by the models and that from official sources behave similarly requires first to identify the native distribution expressed by this variable in each model. With the use of statistical software a series of parameters are calculated to help identify what distribution fits each data set best.⁶⁰ Once a distribution for this variable is identified for each model, it can be used to determine if the official data for patents from each country fall within its percentiles. If these data fall within the projected distribution range, then it can be established that both behave similarly and that the formal data validate those produced by the model.

For the case of Spain the variable capturing the behavior of patented knowledge displays a Lognormal distribution.⁶¹ Information produced by the Fundación Genóma España shows that between the years 2000 and 2008 the average number of modern biotech patents filed in Spain was 125. It further suggests that the number of patents ranged from 81 in 2000 to 200 by 2008 (Genóma

⁶⁰The parameters assessed are the Anderson-Darling (AD) statistic value, the p-value, and for cases with 3-parameter distributions, the Likelihood-ratio test p-value (LRT P).

⁶¹These data display an AD of 0.524 and a p-value of 0.174. This information also provided a location of 5.00321, a scale of 0.17496, and threshold of 0.0

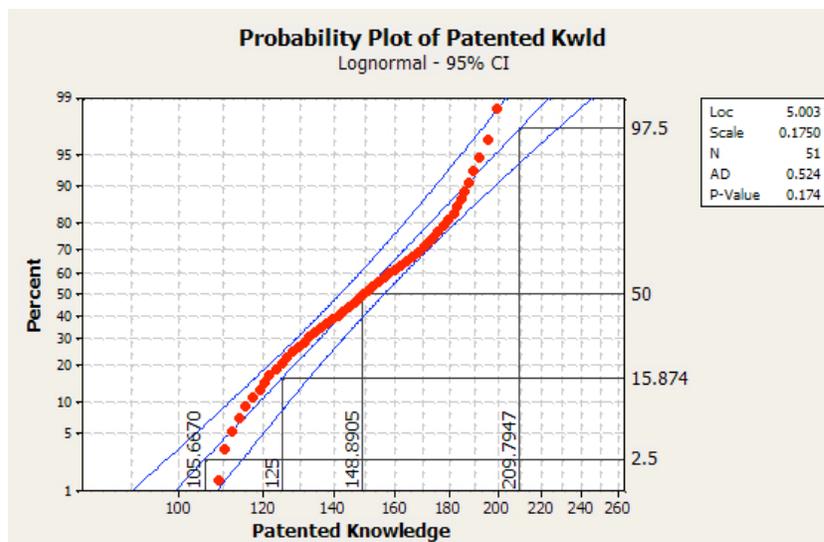


Figure 3.30: Spain: Probability Plot for Patented Knowledge

España, 2009). Using these figures and the probability plot for patents produced by Spain’s model, it can be established that such average falls almost within the 16th percentile. Although this percentile appears to be a low one, the actual median of 149 patents (50th percentile) is not too far off from this level. Doing the same to determine the percentile for a level of 200 patents, which represents the number of patents for the year 2008, suggests that such quantity corresponds to the 95th percentile.

With information for both points it can then be inferred that nearly 80% of all the estimations for patent production using this model fall within the 125 and 200 range and, thus concur with the behavior of the existing formal facts. Although the models calculate future levels of patents, the similarity expressed by the actual and projected data provide enough information to validate their performance (see figure 3.30).

In Mexico data for modern biotech patents are not as systematically produced as in Spain. As mentioned previously, the information used in this research to determine the number of modern biotech patents in Mexico was

mainly compiled from the AMC's study on the state of modern biotech in Mexico (AMC, 2010).⁶² In its appendix on patents, this study suggests that a total of 186 patents were produced in this area in 2008. Although partial, this information can still be used to validate the results produced by the adapted model for Mexico following the same methodology used to validate the data for Spain. In this case the data produced by the model follow a normal distribution and the probability plot for these determine that the level of 186 corresponds to the 96.5th percentile.⁶³ Being this level that of the last year within the 2000 to 2008 continuum, this percentile does not appear to be too extreme. Furthermore, it almost matches that available for Spain in that same year. Although the number of modern biotech patents for the year 2000 in Mexico is not available to determine how well the official information for patent match that produced by the model, it is not too far fetched to conclude that the number of patents for that year was lower than that estimated for 2008. Furthermore, this fact does not impede inferring that the behavior of the data for patents available in Mexico agrees as well with that of the information produced by the model representing its MBTS (see figure 3.31).

Contrasting Mexico and Spain

The results obtained for each of these two adapted models provide more insights about their strengths and weaknesses as well as initial hints of their overall differences. However, a more detailed analysis contrasting the response of all 15 variables at each of the three time periods reviewed offers additional data to

⁶²Another consulted source was the OCDE's biotechnology statistics 2009 (van Beuzekom and Arundel, 2009). However, the number of patents that this compendium provides for each country offers only fractional counts on Patent Cooperation Treaty (PCT) filings at international phase (EPO designations). The AMC compendium includes all local filings for Mexico and thus, can be considered more complete for the purpose of this research.

⁶³These data show an AD of 0.481, a p-value of 0.223, and display a location (mean) of 141.351 and scale (standard deviation) of 24.4854.

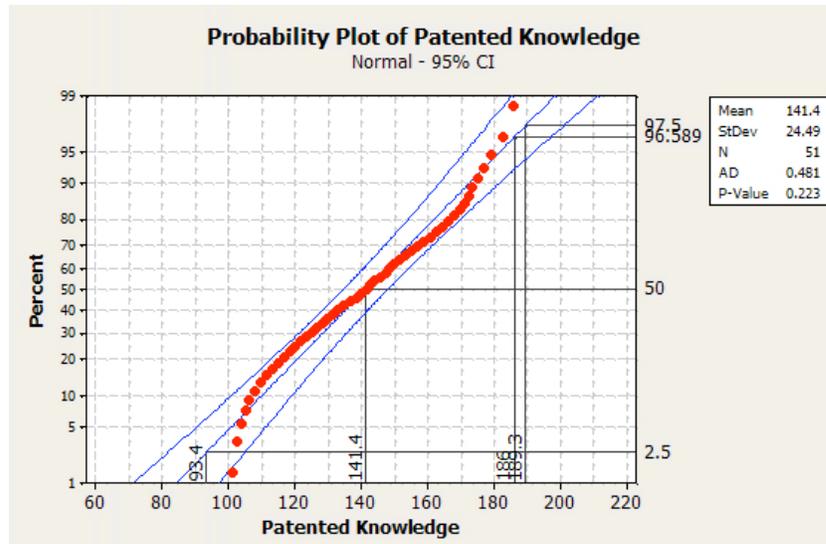


Figure 3.31: Mexico: Probability Plot for Patented Knowledge

help establish if any of these systems —as represented by the model— is in fact more efficient than the other. The outcome of this process (presented in table 3.11) shows that, in the short term, Mexico’s MBTS performance (as measured by variable response) is below that of Spain’s in 8 of the 15 assessed variables.

In particular, the response of those variables measuring R&D potential, patented and open access knowledge production, R&D infrastructure, venture capital going to both activities,⁶⁴ and government income are below those for Spain. Yet, with the exception of patented knowledge and venture capital for development, most variations are below the single-unit difference mark (between 0.05 and 0.89). Furthermore, the response of those variables measuring the levels of new knowledge and new innovations, as well as that assessing the degree of new marketable products and services created by the system — considered as the most relevant to the study— demonstrated to be above those estimated for Spain in this term. These facts suggests that —in the short term—

⁶⁴Although the model for Mexico does not include either type of venture capital, these variables are considered among those contrasted to clearly expose the effects of the virtual absence of these type of resources in that country’s system.

Table 3.11: Contrasting Mexico Current and Spain

Response Variable	Years ¹			
	1	5	10	25
New Research	1.45	0.67	-0.02	-0.75
Research Potential	-1.41	-0.89	-0.72	-1.40
New Development	0.17	0.01	-0.21	-0.37
Development Potential	-0.98	-0.63	-0.97	-2.37
To Market	0.19	0.09	-0.10	-0.09
Patented Knowledge	-15.06	-11.82	-9.32	-8.84
Open Access Knowledge	-0.31	-0.09	-0.11	-1.31
Research Infrastructure	-0.65	-0.43	-0.26	-0.13
Development Infrastructure	-0.78	-0.73	-0.70	-0.63
Government Income	-0.05	-0.05	-0.05	-0.07
VC to Research	-21.24	0.00	0.00	-128.55
VC to Development	-794.31	-1043.41	-1345.79	-1876.14
Genetic Resources	0.00	0.00	0.00	0.00
Biosafety	0.05	0.03	-0.02	-0.37
Health Safety	0.01	0.01	-0.01	-0.22

¹Difference in response taking Mexico as base.

Mexico’s model appears as being more efficient than Spain’s in the promotion of both research and development in modern biotech and in setting the necessary environment for new products and services derived from this technology to arise. Nevertheless, further analysis shows that—in later terms— these advantages dissipate.

Contrasting the variable’s response in the mid term, the number of these performing below Spain’s model increases from 8 to 13. Among these are now the three assessing the levels of new knowledge, new innovations, and marketable products as well as both measuring the system’s risk safety mechanisms biosafety and health safety. Here, development potential joins patented knowledge and venture capital to development as one of the variables with most evident difference in response, almost going beyond the single-unit difference

mark.

In the long run, with the addition of venture capital going to research, the number of variables showing a response below that obtained for Spain further increases to 14. Concurrently, the difference in response between those variables already below becomes more acute, favoring Spain's treatment as more capable of eliciting a positive response from most key variables in this and the previous term.

These initial findings allow reaching the partial conclusion that—at least in the mid and long terms—the modeled version of Spain's MBTS not only displays a stronger potential to generate new knowledge and innovation, but also a more solid capacity to create markets for new technologies derived from modern biotech than that of Mexico. Based on these findings it can also be inferred that there is a high probability that Mexico's MBTS would outperform its current modeled structure—as measured by the response of a number of selected variables—if it were to include those structural differences defining the model for Spain. These conclusions, however, do not allow to fully falsify the earlier proposed null hypothesis suggesting that Spain's MBTS outperforms that of Mexico.

3.3.4 Mexico Adapted to Best Treatment

The conclusions obtained in the previous section put forward the notion that tweaking Mexico's model enough to resemble that of Spain can allow it to display a more significant variable response than the one it currently exhibits. In other words, applying the "All On" treatment to Mexico's model could make it perform more efficiently. Yet, earlier findings also show that—if initial conditions are kept constant—a treatment proposing all structural elements charac-

terizing Spain's model plus variations to the IPR framework in the form of both less breath and length for patents is an even better variable response-inducing option. Following this prescription, when the "All On-IPRL-IPRB" treatment is applied to this model, the response of most of its variables increases, corroborating that such resulting system is more efficient than that initially modeled for Mexico and possibly more than one solely including Spain's traits. Moreover, these results assist producing additional policy recommendations on how to make Mexico's actual MBTS operate in a more efficient manner. This section presents the outcome of these contrasts. As for the previous models this required 1) running the altered model 100 times and recording and analyzing its effect over each variable at every time period; 2) using the mean for each time period of simulation (meaning the arithmetic mean of 100 observations per dt) to define a single general observation per dt for each response variable; and 3) using these points as input to run time series regressions to obtain the specific trend lines that describe the effects of the treatment has on the response variable over time (see table 3.12).

Being information less appropriable and free-access in less time in this resulting model, it can be initially assumed that private investment—generally more intensive in development activities— would decrease. Yet, contrary to this, *VC to Development* becomes a pivotal variable displaying the largest degree of change throughout all three periods analyzed, ranging from an initial 244.86 level up to 1,405.7 in the long run, an overall 474.06% growth in investment for the sector.

The response of variables capturing the performance of both research and development also shows a system with both an increased potential and capacity to produce new knowledge and innovations. In particular, *New Research*

Table 3.12: Adapted Model for Mexico: Parameters for Selected Variables to “All On-IPRL-IPRB” Treatment

Response Variable	Equation Parameters							
	MAPE	MAD	MSD	Asymptote	10^a	β_0	β_1	β_2
New Research ^a	25.1571	0.6321	0.7840	-	-	3.7080	0.1352	-0.0023
Research Potential	1.7828	0.3630	0.2210	22.4073	100	4.4503	3.7987	0.7766
New Development ^a	16.4983	0.5677	0.5345	-	-	2.9670	0.2160	-0.0036
Development Potential ^a	2.8335	0.5339	0.4231	-	-	15.385	0.3823	-0.0062
To Market	32.0764	0.2769	0.1281	-3.1782	10	-3.1465	21.0768	0.9849
Patented Knowledge	12.8000	16.8000	1364.2600	46.1576	1000	21.6649	-19.6538	0.9677
Open Access Knowledge ^b	5.2698	0.2747	0.1382	6.8617	100	14.5737	19.1550	0.8665
Research Infrastructure	0.1530	0.0127	0.0004	9.0626	100	11.0344	1.7445	0.9534
Development Infrastructure	0.7892	0.0606	0.0052	-22.7861	100	-4.3886	17.9865	0.9986
Government Income	0.2250	0.0195	0.0008	8.4163	100	11.8817	-0.2433	1.0090

Continued ...

Table 3.12: (continued)

Response Variable	Equation Parameters							
	MAPE	MAD	MSD	Asymptote	10 ^a	β_0	β_1	β_2
VC to Research ^b	-	-	-	-	-	-	-	-
VC to Development ^{a,c}	11.8000	132.9000	40474.0000	-	-	40.7000	105.2000	-1.5580
Genetic Resources	0.0019	0.0001	0.0000	7.0015	100	14.2826	0.0024	1.0482
Biosafety	1.2192	0.0896	0.0139	8.5104	100	11.7503	3.3576	0.9638
Health Safety	0.6146	0.0441	0.0029	10.3232	100	9.6870	4.8566	0.9939

^aThe parameters for this variable were estimated using a quadratic trend line model

^bWhen running the system dynamics model using these settings, the output for this variable was always equal to zero

^cData converted using square root.

End

displays more growth in the mid than in both the short and long terms (21.78%, 38.76%, and 21.19%, respectively), moving from an initial production capacity of 3.97 up to 5.51 in the mid, and later down to 4.81 in the long run. Although *Research Potential's* response maintained an increasing tendency, it also showed less growth in the long term than in both the short and mid (41.82%, 50.66%, and 51.48%, respectively). This variable went from an initial 14.83 level up to 22.35 in the mid, and later further up to 22.47 in the long run. *New Development* and *Development Potential* showed a similar behavior to that of these variables, both expressing growth at decreasing rates (see table 3.13).

As the central variable measuring the system's performance, the response of *To Market* expressed a considerable overall 157.87% expansion, increasing from an initial 0.58 new product per cycle capacity up to 1.49 in the long run. The collective improved performance of these variables, particularly of *To Market*, allows to suggest that—in conjunction to an investment expansion in development activities—a reduction in both the breadth and length of IPRs may have sufficient positive leverage on the overall system's performance. Although this assertion requires further empirical testing, it is plausible to infer that—like in this model—amplifying information and knowledge's rate of flow may result in a more efficient market creation system for biotech.

As a result of these changes the variable *Patented Knowledge* displays a reduction much steeper than that seen in the original model, going from initially producing 306.78 patents down to 56 in the long run, an almost 82% overall reduction. In this setting *VC to Research* also performs among those less responsive variables, displaying zero growth in all terms. This last variable's behavior may be due to the fact that—in all model versions—the main incentive for private investment in research derives from the degree of returns obtained from

Table 3.13: Adapted Model for Mexico: Response
 from Selected Variables to “All On-IPRL-IPRB”
 Treatment

Response Variable	Treatment				Response			
	Initial	Short	%Change	Mid	%Change	Long	%Change	
New Research	3.97	4.83	21.78	5.51	38.73	4.81	21.19	
Research Potential	14.83	21.04	41.82	22.35	50.66	22.47	51.48	
New Development	3.38	4.77	40.97	5.86	73.26	4.88	44.09	
Development Potential	16.12	18.59	15.27	20.55	27.44	18.99	17.75	
To Market	0.58	0.67	15.65	0.81	39.46	1.49	157.87	
Patented Knowledge	306.78	133.16	-56.59	87.18	-71.58	56.00	-81.74	
Open Access Knowledge	3.45	5.22	51.25	6.38	84.85	6.85	98.48	
Research Infrastructure	7.92	8.25	4.15	8.54	7.81	8.93	12.73	
Development Infrastructure	7.38	7.49	1.46	7.63	3.32	8.06	9.16	
Government Income	8.60	8.61	0.16	8.63	0.37	8.69	1.15	

Continued ...

Table 3.13: (continued)

Response Variable	Response						
	Initial	Short	%Change	Mid	%Change	Long	%Change
VC to Research	0	0	0	0	0	0	0
VC to Development	244.86	936.9	282.61	1521.5	521.36	1405.7	474.06
Genetic Resources	7.00	7.00	-0.01	7.00	-0.02	6.99	-0.16
Biosafety	6.73	7.11	5.66	7.49	11.33	8.14	21.07
Health Safety	6.90	7.02	1.62	7.15	3.61	7.54	9.28
End							

licensing patents to development or back to research, which in this case are decreasing. Thus, making investment in development more attractive for venture capital investors, due to the increased returns generated by products and services reaching the market.

Although not necessarily performing inefficiently, the variables measuring the levels of available infrastructure for both research and development show a more conservative response than that of most variables associated to these sectors. In particular, *Research Infrastructure's* response grows slightly above that of *Development Infrastructure*, going from 7.92 to 8.93, and overall 12.73%, while the latter increases its capacity from 7.38 to 8.06, a 9.16% variation. In this model *Government Resources* also shows a moderate growth, increasing 1.15% to change from 8.60 up to 8.69. The response of these three variables in all three periods, however, is above that obtained using the original model's configuration, further corroborating this model's superior performance.

Among the resource-assessing variables, *Open Access Knowledge* presented the most evident response increment. Benefitting from the reduction in both IPR length and breadth introduced by this treatment, it achieved a constant growth in all three terms (51.25%, 84.85%, and 98.48%, respectively). However, this variable's higher response is not as substantial as expected when contrasted to that previously obtained using the original model's configuration. Therefore, suggesting that the theoretical changes in the way property over knowledge is managed in this model are in fact less radical than they appear. Conversely, *Genetic Resources's* long-term decrease in response in this model hints on the existence of some adverse effects deriving from a more rapid new knowledge production pace, which may also stem from the proposed reduction in IPR protection.

Lastly, the response of both *Biosafety* and *Health Safety* increases in all three periods (an overall 21.07% and 9.28% expansion, respectively), capturing a rise in the demand for these services. This behavior is associated to an expansion in the production of marketable products requiring these reviews and further supports a better performance of this alternative system.

Contrasting Mexico with Best and Spain

When the response of all 15 variables are contrasted, the superior performance of this alternative system becomes evident (see table 3.4). In the short and mid terms only one variable, *Patented Knowledge*, displays a change inferior to that obtained by the original model, in this case a steeper reduction in the level of existing patents. Under this treatment all other variables showed in both of these terms a higher response, especially *VC to Development*, which was originally absent in the first model.

Contrasting these results with those obtained for Spain, however, offers a less clear outlook of this model's efficiency (see table 3.5). In the short and mid term only 5 variables (*Patented Knowledge*, *Research Infrastructure*, *Development Infrastructure*, *Government Income*, and *VC to Development*) display a less efficient response. Yet, further contrasting shows that, in the long run, the number increases to 11. Despite the more than twofold increase in variables with less response, (almost up to 14 obtained in this period when contrasting Spain and Mexico's original treatment), the outcome for the pivotal *To Market* in all three terms is above that of Spain, suggesting that this model is in fact better suited for producing more products and services derived from this technology than either of the two previously analyzed.

These results and a deeper analysis of all previous findings serve as the ba-

Table 3.14: Mexico: Contrasting Current and Best Treatment

Response Variable ¹	Years			
	1	5	10	25
New Research	0.42	0.65	0.79	0.15
Research Potential	-2.67	2.05	2.18	1.10
New Development	0.80	0.93	1.00	-0.60
Development Potential	0.34	1.31	2.49	0.55
To Market	0.15	0.13	0.11	0.26
Patented Knowledge	125.95	-34.64	-63.96	-46.54
Open Access Knowledge	-0.02	0.82	1.12	0.69
Research Infrastructure	0.00	0.00	0.00	0.03
Development Infrastructure	-0.11	0.02	0.17	0.58
Government Income	-0.01	0.00	0.02	0.07
VC to Research	0.00	0.00	0.00	0.00
VC to Development	244.87	936.90	1521.50	1405.70
Genetic Resources	0.00	0.00	0.00	-0.01
Biosafety	-0.24	0.07	0.35	0.69
Health Safety	-0.09	0.02	0.15	0.47

¹Difference in response taking Best Treatment as base.

sis for a number of policy recommendations for the consideration of decision makers working within Mexico's MBTS framework presented in the following section.

Table 3.15: Mexico: Contrasting Best with Spain

Response Variable ¹	Years			
	1	5	10	25
New Research	1.86	1.32	0.77	-0.59
Research Potential	-4.08	1.15	1.46	-0.30
New Development	0.97	0.94	0.79	-0.97
Development Potential	-0.63	0.68	1.52	-1.82
To Market	0.34	0.22	0.01	0.18
Patented Knowledge	110.90	-46.46	-73.28	-55.38
Open Access Knowledge	-0.33	0.73	1.02	-0.62
Research Infrastructure	-0.64	-0.43	-0.26	-0.11
Development Infrastructure	-0.88	-0.71	-0.53	-0.05
Government Income	-0.06	-0.05	-0.03	0.00
VC to Research	-21.24	7.37	16.98	-128.55
VC to Development	-549.45	-106.51	175.71	-470.44
Genetic Resources	0.00	0.00	0.00	-0.01
Biosafety	-0.19	0.09	0.33	0.32
Health Safety	-0.08	0.02	0.14	0.25

¹Difference in response taking Best Treatment as base.

CHAPTER 4
POLICY RECOMMENDATIONS, RESEARCH PROSPECTS, AND
THEORETICAL CONSIDERATIONS

4.1 Lessons Learned

Throughout its brief history, modern biotech has been associated with—and sometimes overshadowed by—a series of issues rather than to a complex and wavering network of innovation systems with paramount development and welfare implications. Due to their salient nature, these issues often eclipse the socio-economic importance of the outcomes of such systems for health, agriculture, and food production. As a result, policymakers working for the advancement of R&D concentrate more on the design of rules for addressing these issues rather than on promotional policies that could further foster the establishment of connections between basic and applied research institutions, firms transforming discoveries into innovations, and the many geo-political entities that collectively weave the networks in which knowledge of modern biotechnology develops. Furthermore, the sources of these issues are oftentimes not fully appreciated by many a decision maker. As suggested by this study, this has partially encouraged regional differences in the level of sophistication and efficiency of these systems.

From a theoretical analysis perspective, the research of modern biotech has encountered limitations as well. With few exceptions, the study of its reaches, ramifications, and implications in the production, distribution, and consumption of goods and services has been pursued using tools from mainstream economics as if it were yet another conventional industrial sector. However, the profound changes in the mechanisms of knowledge production it so far has in-

duced (entirely new knowledge bases, human capital, methods for accessing resources, and infrastructure), combined with the nature of knowledge itself and that of some of its resulting innovations—both displaying intangible quasi-public good traits—call for alternative analytical approaches for its study. Some that can capture more accurately the economic growth effects that this technology brings about. More specifically, the design of methods for the study of the dynamics of the multiple public and private agent networks engaged in both knowledge production and transformation, how these come to be, and the ways knowledge itself—as a resource—behaves within these.

This closing chapter presents a list of recommendations for policy makers in Mexico on how to promote modern biotech locally. These are based on the findings obtained from the various alternative thought experiments performed here to assess and contrast the behavior of Spain and Mexico's MBTS. It also offers a section with research suggestions and theoretical questions encouraging academics and professionals to engage in the design of alternative thought experiments to achieve both a deeper understanding of the role that this approach plays in knowledge production activities and in the advancement of modern biotech in Mexico. Overall, these conclusions and recommendations aim at helping develop new theoretical approaches for the study of the economics of technological change and innovation. In doing so these also aim at adding to the ongoing conversations on how to bridge the 'Systems of Innovation' approach for explaining regional knowledge-based economic performance with the methodology and mathematical modeling technique for framing, understanding, and discussing complex issues put forward by 'Systems Dynamics.'

4.2 Policy Recommendations and Research Prospects

Over half a decade has passed since the enactment of the *Biosafety of Genetically Modified Organisms Law*, the last considerable effort by Mexican policymakers to advance modern biotech locally. Although its by-laws were enacted in 2008, which remain in continuous evolution, no endeavor of this caliber has been orchestrated by the local governments to further promote the use and expansion of this technology since. In addition, the lack of noticeable and tangible outcomes, beyond those seldom heard from being developed in public research centers, in the form of new start-ups, products, or services emanating from the application of this technology further suggest that solely addressing biosafety has not been sufficient an effort to achieve a full launch of this sector locally.

Overall, the conclusions obtained in this study allow: 1) presenting modern biotech from a systems of innovation perspective; 2) producing a concise list of recommendations that can serve as reference for the design of policies to revamp the current MBTS operating in Mexico; and 3) uncovering new research avenues associated to this methodology —and technology— both locally and globally. In general, these findings suggest that:

- Mexico's system as modeled is, in the short term, more efficient than that modeled for Spain, especially in the creation of new marketable products and services deriving from this technology.
- Further analysis, however, determines that the system is deprived from this advantage in the later mid and long terms and becomes considerably less efficient than that modeled for Spain in various other areas.
- When Mexico's system is supplemented with specific institutional and regulatory elements —most which are present in Spain's MBTS— its per-

formance improves above that of its current state and beyond that of Spain in particular key areas, including market creation.

- There are some limitations to the use of this approach deriving mostly from a lack of qualitative and quantitative data, especially for the case of Mexico. Such absence, however, generates a series of research opportunities both locally and globally that—if explored—can assist to better assess the behavior of these systems and, thus, of modern biotech.

These conclusions serve as the basis for the following policy recommendations and research prospects.

Structural, Regulatory, and Political Recommendations

1. **Mexico should take note of the elements making Spain’s system work more efficiently but avoid trying to replicate these verbatim locally.** As much as these appear to be working for Spain, the geo-political and idiosyncratic differences between the various regions of these two countries suggest the need for the design of more “tropicalized” versions that address the local needs and wants. Instead, policymakers should consider their central traits and aim at:

- Developing more tangible channels between regional and national research centers;
- Making the sector more attractive for local and international venture capital investors;
- Collaborating with states and regions to develop incentives that promote R&D clustering;

- Working on the design of rules that allow regional labor mobility (within the framework of NAFTA);
- Pursuing the establishment of public investment funds for research projects;
- Setting the environment for public-private projects to foster; and
- Establishing rules to induce the formation of connectors between the results of research and the demands of the innovation sector.

This last element suggests providing the means for the private sector to articulate a fully-operational financial system for new technologies, especially for those deriving from the NLS. Furthermore, the instruments traded in it should be promoted at the local and regional levels, with the federal government serving exclusively as coordinating entity, in order to diversify the risks of particular national interest projects.

2. **Local policymakers should engage in a thorough analysis of the implications that changes to the IPR system could have and how these could affect private investment in the sector.** This study suggests a policy that merges particular key components of Spain's MBTS and changes to IPRs as the most promising for advancing Mexico's modern biotech sector. Yet, since the private sector, as engine behind the development of marketable innovations, is sensitive to changes in the rules governing private property protection, this recommendation requires taking particular considerations before being implemented. Information and new knowledge being the most valuable assets emanating from this technology's research activities, it is extremely important to maintain a balance between the resulting positive effects for the sector of reducing IPR protection over discoveries—as suggested in this study—and the incentives these as instruments provide

for current and future private entrepreneurs. If this path is to be pursued, the Mexican government should consider the design and coordination of participatory mechanisms in which IPR experts, private sector investors, researchers, and other key actors operating within these networks become informed of the possible trade-offs derived from changes to the IPR system while, simultaneously, allowing these to provide their insights and expertise on how these might affect future R&D practices.

- 3. Review its international regulatory frameworks on trade and foreign investment.** With the rise of China as the world's manufacturing power, Mexico has been working much harder to attract investment from the US and other economic regions. Drug-related violence aside, Mexico's economy has remained relatively stable throughout the last decade and has kept a free-market economy mentality promoted by the political party currently in power. Its closeness to the US and Canada allows it to further compete with China by making it tentatively more attractive for industries and research centers that look forward to moving large enterprises to more cost-efficient areas to migrate there. First and foremost because moving these across the border would be less costly and time consuming than transferring them across the Pacific Ocean. Additionally, the development of a fair regulatory framework controlling the access to the abundant local genetic resources can serve as further incentive for the establishment of such research initiatives in particular regions of Mexico. The richness and accessibility of yet unexplored animal, vegetable, insect, fungi, and bacterial genetic material found in areas like Mexico's southeast *Altos* or in its central *Bajío* valley, plus the readability of these regions to house such clusters is almost unparalleled. Also, the relatively increasing number of local

researchers in modern biotech (nearly 2,100 according to INEGI statistics)—most of them educated and trained in the best laboratories and research centers in the planet— help to offer high quality human capital locally at competitive costs. This effort, however, would require the Mexican government to update rules on international investment in national territory and policies behind the local funding allocation for public R&D infrastructure.

4. Local authorities should look forward to working together with the US and Canada on the design and establishment of more effective mobility options for human capital operating in modern biotech-related areas.

The current system offers a limited number of options within NAFTA's framework, and most are exclusively business and trade related. To some extent, this is something that can be adopted from the EU, where the free flow of professionals, investors, and other individuals participating in modern biotech-related R&D processes (and in other associated development areas) is completely unrestricted. This would allow researchers, investors, and business agents to move more freely between research and industrial centers from either country without having to change their migratory or visa status and, thus in less time. It can also help homologate salaries and fast-track the transferring of research or innovation projects from one specialized facility to another, allowing these to continue punctually.

5. Engage in efforts to explain the connections between modern biotech and intellectual property rights. Although not exclusive to Mexico, there still is a general lack of understanding of the links existing between intellectual property and genetic engineering. This gap has especially worked

in detriment of this technology by fostering the rise of a series of misinformed arguments, like those suggesting that full property can be claimed over individual genes. This also induces perverse incentives for private investors who —likewise— can be inclined to believe that the only way they can benefit from investing in basic research activities is by obtaining unlimited property over discovered genes. Both distorted views exert a considerable toll on the development potential of this technology; the former stigmatizing biotech and its outputs among the general publics, the latter inhibiting investment in the sector. Particular recommendations to help reduce this information gap can be:

- Organize on-site and on-line seminars (coordinated by the local Mexican Industrial Property Institute, along with CIBIOGEM and CONA-CyT), with the objective of informing individuals with particular interest in the sector and a desire for acquiring a deeper understanding of modern biotech about the connections between these two areas. **Echoing the international professional certification process, all successful participants could obtain a ‘certification’ in industrial biotech valid within the NAFTA and EUFTA frameworks.** Forums could be divided into various modules, each taught by experts representing different areas (research, development, investment, etc.) and selected through inclusive participatory procedures. These processes would not only allow a reduction in the breach in understanding, but also help level the playing field in which discussions regarding IP and modern biotech take place.
- Engage the various local governments in the design and dissemination of properly orchestrated information campaigns (Internet, tv, ra-

dio, printed means, etc.) aimed at particular audiences, in a quest to further explain the industrial relevance of modern biotech. Although similar schemes have been tried before, decision makers should make efforts to make sure the design and message of these is completely unbiased.

- Define more specific provisions for modern biotech within the *Industrial Property Law*. Policymakers should at least target working in the development of a particular chapter within this legislation dedicated exclusively to modern biotech. Also, they should make an effort not to address biosafety issues in this tentative chapter.

These informative, certification, and regulatory processes could help turn modern biotech into a more approachable technology not only for representatives of particular productive sectors (health, agriculture, food production) but also for representatives of other sectors —like those in the liberal arts— as well as for the general public.

6. **Look for processes to differentiate modern biotech from biosafety.** Quite often the meaning, reaches, and scope of modern biotech is mistakenly believed to be that of biosafety, and vice-versa. While the former can be considered as a dynamic network of technological systems of innovation in which R&D processes take place for the discovery and application of new knowledge, the latter can be defined as a series of procedures to reduce the risks deriving from these (and other) processes that can pose threats to human life and to the balance of living ecosystems of the planet. Although clearly different areas, the symbiosis existing between these two seems to encourage this ongoing confusion. As modern biotech advances, the demand for more precise and sophisticated biosafety processes will

help create new markets for services. As the design of new policies will be required due to this, making sure that the various publics associated to both sectors —policymakers included— understand their difference is of the utmost importance for the advancement of this technology locally.

7. Produce as many “biotech businesspersons” as “biotech researchers.”

Most entrepreneurial initiatives emanate from business-trained individuals than from highly technical human capital (researchers), as some Spanish experts suggest. With very few exceptions, the majority of graduate programs associated to modern biotech in Mexico are exclusively research oriented. Trying to either transform a researcher into a business entrepreneur, or the opposite scenario, is quite difficult —if not impossible— a task (as implied in various views presented in chapter 2). If, instead, programs focusing exclusively on the business of modern biotech were tailored in the many private universities and colleges offering MBA programs in Mexico, an entirely new sector of entrepreneurs could be fostered locally. These would not only understand the intricacies of business creation but would be knowledgeable of the “language” spoken by hardcore researchers and technically trained personnel. This, in time, could induce the formation of channels between business and research, some that could end up in the establishment of many a new start-up. Moreover, it could also induce the rise of local biotech venture capital fund managers, as MBA programs specialize in the finance of biotech, further helping create the market system suggested earlier in point 1.

8. Take advantage of the IT Revolution to create a national network of biotech research centers. Establishing virtual connections between research centers using the Internet is as important as developing physical

clusters for production processes. Being most of the new knowledge and information obtained from genetic engineering research activities in electronic format, its flow within these networks can almost be instantaneous. Moreover, it can be simultaneously shared between multiple centers. Researchers can take advantage of the various Internet programs that virtually allow face-to-face interaction, as these can facilitate collaborative initiatives and other participatory processes among colleagues physically working in different research centers. These centers could even look forward to contracting local software and IT network developers for the design of specialized and more secure networks and the management and storage of information, further encouraging the creation of new markets for services linked to this technology. In addition, to promote the establishment of these connectors, the federal government should aim at advancing the rules for the protection and sharing of electronic data.

9. Foster the creation of “connectors” and “match-making” institutions.

More than a step-by-step prescription, this can be accomplished by setting the ‘appropriate environments’ for such connections to rise by themselves. With few exceptions, like establishing regional research clusters that assist creating connections between the multiple stakeholders and their initiatives, facilitate technology transfer, and induce entrepreneurial business activities—echoing the Bio Regions operating in Spain—the government should only aim at enacting the necessary regulations and designing the appropriate policies that allow these institutions to rise. Such regulations and policies could consider, among other principles, the points previously expressed here.

10. Define a clear and pragmatic government position regarding modern

biotech. There is no clearer message to tentative investors than the stance a central government takes with respect to a particular technology. If the Mexican government manages to display clear and unambiguous support for modern biotech, the design of numerous promotional policies in this area will follow. This can help include modern biotech processes in the production of basic products and services that the federal government demands in areas like health, agriculture, food production, materials, biorremediation, etc. As the demand for these products and services rise from government procurement, the establishment of more public funding for R&D activities, the development of competitive human capital, a rise in local and regional industrial transformation, and an expansion in public-private ventures, among many others with profound implications for local development and economic growth, will also follow.

Research Opportunities

This dissertation has opened up several opportunities for further investigation of the questions addressed herein, including the following four.

1. **Producing formal data for modern biotech.** Although a number of international organizations regularly produce data on modern biotech for various countries, including Mexico (OECD, WTO, FAO, etc.), few are the sources that produce such information locally (AMC, CONACyT, AgroBio, etc.). The scarce local data available are neither systematically compiled nor structured enough to be used in regional or international economic development studies without having to go through substantial manipulation beforehand. Studies like this one required merging information from multiple sources to generate comparable data and statistics to

those available in Spain. The absence of such information in standard form not only handicaps the systems of innovation/systems dynamics approach but also curtails the success of mainstream methods also followed to understand the economic development effects of modern biotech. Mexico needs to invest time and resources in research that helps develop this type of structured information in a manner similar to that seen in other economies. Yet, such data will have to go beyond exclusively capturing statistics for agricultural and pharmaceutical modern biotech; requiring further examination of areas like human capital, infrastructure, intellectual and industrial property, genetic resources, and many others of economic relevance for the sector. International organizations —like the OECD— have already developed guidelines to “standardize” these types of aggregate statistics¹ and there are plenty of other references worldwide to obtain guidance from. A starting point could be to supplement the economic census to be produced by Mexico’s National Institute for Statistics and Geography, INEGI in 2014 with questionnaires and surveys that capture exclusively the performance and economic impact of modern biotech-related areas.

- 2. Fine-tuning research design and information gathering methods for the study of modern biotech.** When engaged in research design for a project to assess the economic implications of a sector —whether using this approach or not— it is difficult to estimate before hand how and what information has to be collected. This process becomes even more complex when trying to define what methods and instruments are optimal to obtain the type of information that can be both qualitatively and quan-

¹These are presented in the document: “A Framework for Biotechnology Statistics.” OCDE 2005.

tatively relevant as well as useful to establish connections and associations within a network of systems. Even more so when the sector being reviewed is still at developing stages. Both expertise in research design and information collection methods, however, can generally only be acquired through hands-on experience. Therefore, a refinement in both the way research methods are taught and data gathering is practiced for modern biotech-related studies should be explored in more detail in Mexico. Creating courses where both the theory and practice of these areas is fostered—especially for studies based exclusively on the systems of innovation/systems dynamics approach—is pivotal for the advancement of research in this area locally.

3. **Refining elicitation.** Having the capacity to double-check if the results of a particular research indeed capture what happens in the “real world” is something of great value for any researcher. *Post facto* elicitation helps validate outcomes and thus, consolidate any approach or methodology followed to obtain these. The design of particular instruments—like cyclical surveys and questionnaires—can be tailored to guarantee a future reassessment of research outcomes with those actors from whom information was initially elicited from. Research on survey and questionnaire design as well as on ways to define more institutionalized approaches to promote *post facto* elicitation—perhaps through the establishment of associations of “collaborative actors” whose members agree to be accessible for a particular period of time—is a research opportunity that can be explored in Mexico. This research avenue, supplemented with the previous two recommendations, can help produce higher quality information about the behavior and landscape of the local systems of innovation associated

to modern biotech.

4. **Defining a cartography for systems.** For the particular case of the systems of innovation/systems dynamics approach, in order to discern how and what needs to be measured within a system, there is first the need to define “maps” of the system about to be examined. Thus, establishing mapping methodologies is essential for this approach to consolidate as a solid counterpart to neoclassical and other mainstream frameworks followed to understand innovation. Having a more detailed systems cartography would allow pinpointing of standard components and links between these as well as defining of specific measurable parameters in a more direct manner. In Mexico, promoting the development of such a cartography is key for the overall advancement of this approach and for the study of modern biotech using these methods. A way to approach this is for universities and research centers to offer courses that merge methods of systems dynamics, systems of innovation theory, and geographic information systems as part of their economic and industrial organization core course rosters.

4.3 Theoretical Considerations

The following are a series of future tasks to pursue for academics, researchers, and professionals in the study of scientific development to consider that also emanate from this research.

1. **Explore alternative methodologies for the study of knowledge accumulation and exchange.** The approach here allows for the design of dynamic models that can capture the behavior of multiple actors and institutions

composing the networks in which technological change occurs. It also permits determining which elements and networks of these play the most relevant roles and facilitates measuring their sensitivity to structural and policy changes. In doing so, it also allows determining what alternative institutional arrangements could induce a better overall performance of the system. By considering knowledge—the central factor in innovation processes—as a quasi-public good, this methodology presents itself as an alternative to partial equilibrium and endogenous growth modeling techniques in which the behavior of innovation systems is subject to production functions with factors displaying diminishing returns. Being this the first attempt to explicitly merge the study of regional innovation systems with systems dynamics modeling techniques—and certainly its first application for the analysis of modern biotech—it would therefore be interesting to witness further studies using this (or a similar) technique to continue assessing the behavior of this or other technological systems, like IT or nanotech. It would also be interesting to see similar methods applied for the study of artistic expression systems, as these (art, literature, music, etc.) also engage in information and idea-exchange processes for the production of objects with artistic and market value.

2. **Promote a deeper understanding of the limits of intellectual property and how these limits relate to the study of modern biotech.** As mentioned in earlier sections, while challenges deriving from the quasi-public good nature of knowledge and information equally affect all areas of scientific endeavor, modern biotech seems to be more susceptible to these for multiple reasons:

- Access to DNA is virtually as boundless as it is widespread, turning

most efforts in the direction of claiming exclusive rights over its physical parts or the information expressed and contained in it or in any of its parts complex.

- Although some artificially-induced biological alterations and processes may create new organisms or processes not occurring in nature, it is both, the methods followed to produce such changes and the information obtained through them that may be partially protected by IPR regulation. In most cases, however, this is the only subject matter over which IPRs can be filled for, often more than over the resulting GMOs or parts of these. Therefore, this information, more often than not, becomes the single proprietary part of the process displaying the highest commercial value.
- Living GMOs or parts of these, carrying within the results of long and rigorous scientific endeavor, may still display replicating or reproducing capacities and thus, a potential to pass-on such information to their offspring without depleting it and with barely no effort. This capacity reduces further more the likelihood of full appropriability and containment, especially within open environments or natural ecosystems.

Further study of the interactions between IPRs and technological change, from a systems perspective, would continue shedding more light on the transformation of existing and the rise of new legal institutions, and about the incentives behind the actors aiming at altering the limits of what is appropriable in this and other areas.

- 3. Frame scientific development processes as systems of innovation in which knowledge and information is discovered and shared.** As op-

posed to most productive sectors, the knowledge production sector is not one which can be elicited for particular outcomes. This makes determining the economic impact of the sector a difficult task when using conventional economic analysis tools. A systems approach, however, allows to estimate the behavior of the sector and its parts over time. It can help supplement existing estimations or assist in defining associations between actors that can facilitate the design of econometric or other types of economic analysis models. But besides determining the behavior of the sector, the most important aftermath from applying this approach comes from obtaining a deeper understanding of the connections and interactions existing between the multiple actors engaged in innovation processes. In a sense, this approach helps frame knowledge production and dissemination as a network in which the interconnection of creativity, entrepreneurship, tangible and intangible resources, art, design, and —most of all— patience, intersect.

4.4 Final Thoughts

The importance of modern biotech for the development of emerging economies such as Mexico is not even quantifiable. The concise list of recommendations provided helps expose only the tip of the iceberg of the gargantuan adjustments that need to take place in that country for this technology to thrive at some point during this century.

In particular, this research presents just a few considerations stemming from a highly abstract and theoretical project from which many more considerations can be obtained. For some, this methodology as well as some results may even appear to be too far off from those found within mainstream economics of scien-

tific development papers. Yet, one central objective of this study is precisely to present alternative methods and to explore new “theoretical paths” that allow to tackle the analysis of topics that have been identified as difficult to schematize and evaluate using mainstream approaches. I hope the conclusions, the model at its core, and the unorthodox approach of this research provide enough stimulus for others to engage in the design of alternative methods for the study of scientific development in years to come.

APPENDIX A
QUESTIONNAIRE

This questionnaire is the final version used in all interviews conducted in the summer of 2008 in Spain and those in Mexico during the summers of 2009 and 2010.

INTERVIEW QUESTIONS

NAME

AREA

DATE

Time

PART I: OPEN-END QUESTIONS

1. In your view how is science promoted in Spain?

⇒ Probe: How is Modern Biotechnology promoted?
2. Could you point out some channels linking science and technology with the local productive sectors?
3. What institutions participate in these processes?

⇒ Probe: How do non-experts participate in these processes?
4. What is your overall view of the current linkage process?
5. What external policies (say, those established by the EU) have promoted the advancement of these technologies in Spain?

PART II: OPERATIONAL FRAMEWORK

STEP I: STRUCTURE

- What institutions compose the Spanish Biotech Policy Network?

- At the central government level?
- At the state/regional levels?
- What areas of these institutions participate in policy setting?
- What areas of other institutions you deal with the most on these topics?
- Who do you consider as “main actors” (institutional and individual) participating in such policy setting?
- Can you identify other actors participating in the biotech and genomics policy setting protocol beyond these institutions and actors?

STEP II: PERFORMANCE

- In your view what is the overall performance of the current linkage framework?
- What particular areas/elements in your institution you perceive as performing adequately in this sense?
 - That could perform more adequately?
- In your view are there any areas/elements generating delays in the system?
 - Probe: Are there any markets being prevented from existing?

STEP III: FEATURES

- Can you provide what in your view are positive aspects of the current policy framework?
 - Probe: How efficient is it in its goal of advancing these technologies?
- What could be seen as weak aspects of the current framework?

- Probe: What is not being considered within the protocol’s framework? [Organizational, lack/excess elements (institutions)].
- Are there any particular aspects the current framework does not manage you can think of?
 - Probe: How can these aspects be internalized within these guiding principles?

Do you have additional observations or recommendations?

APPENDIX B

APPENDIX: MODEL'S EQUATION (MEXICO)

```
{ VERSION 9.1.4}
{ INITIALIZATION EQUATIONS }
: c R&D.POLICY.Length = 25
: 1 DEVELOPMENT.In_Market = 5
    TRANSIT TIME = 5
    INFLOW LIMIT = INF
    CAPACITY = INF
: 1 RESOURCE.MANAGEMENT.R.Labor = 0
    TRANSIT TIME = 6
    INFLOW LIMIT = INF
    CAPACITY = INF
: 1 RESOURCE.MANAGEMENT.D.Labor = 0
    TRANSIT TIME = 4
    INFLOW LIMIT = INF
    CAPACITY = INF
: 1 INNOVATION.MANAGEMENT.Patent_A1 = 186
    TRANSIT TIME = varies
    INFLOW LIMIT = INF
    CAPACITY = INF
DOCUMENT: It is assumed that there is an initial endowment of 65 units within the patent pipeline before t0.
: 1 INNOVATION.MANAGEMENT.LicR.Clust = 0
    TRANSIT TIME = 3
    INFLOW LIMIT = INF
    CAPACITY = INF
: 1 INNOVATION.MANAGEMENT.LicD.Clust = 0
    TRANSIT TIME = 3
    INFLOW LIMIT = INF
    CAPACITY = INF
: s INNOVATION.MANAGEMENT.Public_Know = 1000
: c INNOVATION.MANAGEMENT.R.Clustering = 1
DOCUMENT: If clustering happens, then information is spilled back to both research and development in the form of
"Free Access Info." This effect can be analogous to a relaxing of the IPRs.
: f INNOVATION.MANAGEMENT.SpillRClust = LEAKAGE OUTFLOW
    LEAKAGE FRACTION = 0.4
    NO-LEAK ZONE = 0
: f INNOVATION.MANAGEMENT.Out.LicRClust = CONVEYOR OUTFLOW
: s INNOVATION.MANAGEMENT.Licensed_R = 0
: s DEVELOPMENT.NDi1 = 1
: s RESEARCH.New_R.Knowledge_A1 = 1
: f RESEARCH.To_Tech.Transfer = RESEARCH.New_R.Knowledge_A1
: c INNOVATION.MANAGEMENT.Match_Type.1 =
IF DEVELOPMENT.NDi1 <1 AND RESEARCH.To_Tech.Transfer >0 THEN 1 ELSE 0
: c INNOVATION.MANAGEMENT.Match_Type.2 =
IF INNOVATION.MANAGEMENT.Match_Type.1 =1 THEN 0 ELSE 1
: c INNOVATION.MANAGEMENT.TTe = EXP(RESEARCH.To_Tech.Transfer)
: s R&D.POLICY.IPR.Effect = 0.8
: c INNOVATION.MANAGEMENT.R2DTech.Transfer = INNOVATION.MANAGEMENT.TTe*R&D.POLICY.IPR.Effect
: f INNOVATION.MANAGEMENT.In_Patent_A1 = LOGN(INNOVATION.MANAGEMENT.R2DTech.Transfer)
: c INNOVATION.MANAGEMENT.IPRs_Transfer_% = 0
: c INNOVATION.MANAGEMENT.Leftover_IP = IF INNOVATION.MANAGEMENT.Match_Type.2 = 1 THEN INNO-
VATION.MANAGEMENT.In_Patent_A1 ELSE INNOVATION.MANAGEMENT.IPRs_Transfer_%
```

DOCUMENT: This can work to suggest a “Clustering Effect” if returned to A1 in addition to “Public Knowledge.” Its degree can also be tuned depending on the clustering degree (If 1 then the full “Leftover IP” loops back to A1. Lower levels will refer to less percentage of flow, and so on. This should be allocated with the “Innovation Management” sector.

In the case that there is no Match type 2 then 15% of Patents goes to Research (assuming that if there is no real demand only about 30% of patents are licensed between R&D.

```
: f INNOVATION_MANAGEMENT.In.LicR = INNOVATION_MANAGEMENT.Leftover_IP
```

DOCUMENT: Since the financial resources to pay for the IPRs licenses are produced by “Research” and “Research” is getting these resources as payment, these are balanced out (out=In=0).

```
: f INNOVATION_MANAGEMENT.Out.A1.R = INNOVATION_MANAGEMENT.Licensed.R
```

```
: c INNOVATION_MANAGEMENT.A1.R =
```

```
IF INNOVATION_MANAGEMENT.R.Clustering = 1
```

```
THEN INNOVATION_MANAGEMENT.Out.LicRCl
```

```
ELSE INNOVATION_MANAGEMENT.Out.A1.R
```

```
: c RESOURCE_MANAGEMENT.eA1R = EXP(INNOVATION_MANAGEMENT.A1.R)
```

```
: c RESOURCE_MANAGEMENT.TeA1R =
```

```
IF RESOURCE_MANAGEMENT.eA1R = 1
```

```
THEN RESOURCE_MANAGEMENT.eA1R = 0
```

```
ELSE RESOURCE_MANAGEMENT.eA1R
```

```
: s INNOVATION_MANAGEMENT.R.Infra = 90000000
```

DOCUMENT: The volume of resources in terms of infrastructure in basic research reaches the 250M and each researcher requires a level of 10,000 per period to produce research. There are 126 research centers and 145 affiliated research units in Spain. It is assumed that each has an approximate budget of 2m and 1m, respectively, per period.

```
: c INNOVATION_MANAGEMENT.Infra.Units.per.Lr = 10000
```

```
: c INNOVATION_MANAGEMENT.R.Infra.L.Capacity =
```

```
INNOVATION_MANAGEMENT.R.Infra/INNOVATION_MANAGEMENT.Infra.Units.per.Lr
```

DOCUMENT: Each Lr requires 1000 R Infra L units to allow for Lr to turn into Human Capital (HC) by multiplying each matching 1 unit of Lr / 100 units of R Infra to A1 or A2. in the Research and Development modules.

```
: s RESOURCE_MANAGEMENT.Available.Lr = 2100
```

```
: c RESOURCE_MANAGEMENT.ELr1 =
```

```
IF INNOVATION_MANAGEMENT.R.Infra.L.Capacity < RESOURCE_MANAGEMENT.Available.Lr
```

```
THEN INNOVATION_MANAGEMENT.R.Infra.L.Capacity
```

```
ELSE 0
```

```
: s RESOURCE_MANAGEMENT.Net.Res.Govt = 430000000
```

```
: c RESOURCE_MANAGEMENT.FixR&D.Fund.Switch = 1
```

```
: c RESOURCE_MANAGEMENT.FixedGovt.Fund = 400000000
```

DOCUMENT: This is the amount of resources the government allots to R&D from other sources of government income. It is estimated that when adding the resources produced by the system and going to these activities, the figure reaches the official levels (for Spain around 500m and for Mexico 400m).

```
: c INNOVATION_MANAGEMENT.D.Clustering = 1
```

```
: f INNOVATION_MANAGEMENT.SpillDClust = LEAKAGE OUTFLOW
```

```
LEAKAGE FRACTION = 0.4
```

```
NO-LEAK ZONE = 0
```

DOCUMENT: The spillover fraction is 0.4

```
: f INNOVATION_MANAGEMENT.Out.Lic.D.Clt = CONVEYOR OUTFLOW
```

```
: s INNOVATION_MANAGEMENT.Licensed.D = 0
```

```
: f INNOVATION_MANAGEMENT.In.LicD =
```

```
IF INNOVATION_MANAGEMENT.Match.Type.1 = 1
```

```
THEN INNOVATION_MANAGEMENT.In.Patent.A1
```

```
ELSE (INNOVATION_MANAGEMENT.IPRs.Transfer.%(INNOVATION_MANAGEMENT.In.Patent.A1)
```

DOCUMENT: This logic suggests that the demand for research patents is full (highly, complete stock is demanded) when development’s technological stock is dry (equal to zero). Otherwise the average of licenced patents is just a fraction (if “Match Making” mechanism exists) or zero (if no “Match Making” mechanism exists) of the total of patented A1.

```
: f INNOVATION_MANAGEMENT.Out.A1.D = INNOVATION_MANAGEMENT.Licensed.D
```

```
: c INNOVATION_MANAGEMENT.A1.D =
```

IF INNOVATION_MANAGEMENT.D.Clustering = 1
 THEN INNOVATION_MANAGEMENT.Out.Lic.D.Clt
 ELSE INNOVATION_MANAGEMENT.Out.A1.D
 : c RESOURCE_MANAGEMENT.eA1D = EXP(INNOVATION_MANAGEMENT.A1.D)
 : c RESOURCE_MANAGEMENT.TeA1D =
 IF RESOURCE_MANAGEMENT.eA1D=1
 THEN RESOURCE_MANAGEMENT.eA1D=0
 ELSE RESOURCE_MANAGEMENT.eA1D
 DOCUMENT: It is Total because the zeros where eliminated
 : s INNOVATION_MANAGEMENT.D.Infra = 32000000
 DOCUMENT: There are approximately 275 biotech industries in Spain (with 107 only in Cataluna and Madrid). These
 have at least 15 individuals working at them in development activities. The total resources these had in 2008 were
 slightly above 180M.
 : c INNOVATION_MANAGEMENT.Infra.Units.Per.Ld = 20000
 : c INNOVATION_MANAGEMENT.D.Infra.L.Capacity =
 INNOVATION_MANAGEMENT.D.Infra/INNOVATION_MANAGEMENT.Infra.Units.Per.Ld
 : s RESOURCE_MANAGEMENT.Available.Ld = 12400
 DOCUMENT: I assume that the labor hand does not reduce itself due to the short period of time this analysis extends.
 : c RESOURCE_MANAGEMENT.ELd1 =
 IF INNOVATION_MANAGEMENT.D.Infra.L.Capacity < RESOURCE_MANAGEMENT.Available.Ld
 THEN INNOVATION_MANAGEMENT.D.Infra.L.Capacity
 ELSE 0
 : c RESOURCE_MANAGEMENT.Effective.Ld =
 IF INNOVATION_MANAGEMENT.D.Infra.L.Capacity >= RESOURCE_MANAGEMENT.Available.Ld
 THEN RESOURCE_MANAGEMENT.Available.Ld
 ELSE RESOURCE_MANAGEMENT.ELd1
 : c DEVELOPMENT.HCd =
 1+(INNOVATION_MANAGEMENT.Public.Know+RESOURCE_MANAGEMENT.TeA1D)*
 RESOURCE_MANAGEMENT.Effective.Ld
 DOCUMENT: There is a need to include a +1 to this equation in order to be able to run the scenario where there is labor
 trade-off. Otherwise, since at points there is no change on human capital due to this variability, there is a division by
 zero when running the model using Euler's method.
 : s RESOURCE_MANAGEMENT.Govt.D = 0
 DOCUMENT: This comes from p.32 GE and represents approximately 14% of the total public subvention to R&D, as
 suggested. It includes both the local and community resources.
 : f RESOURCE_MANAGEMENT.Out.Govt.D = RESOURCE_MANAGEMENT.Govt.D
 : s RESOURCE_MANAGEMENT.VCtoD = 0
 : s RESOURCE_MANAGEMENT.NetFin.ResR = 0
 DOCUMENT: This comes from the total sales reported by public biotech entities (747m). Source: p.69 GE, 2009.
 : f RESOURCE_MANAGEMENT.Out.VCtoD = RESOURCE_MANAGEMENT.VCtoD
 : s RESOURCE_MANAGEMENT.NetFin.ResD = 0
 DOCUMENT: This comes from the total sales presented by the biotech industry in Spain for the year 2008 (684M)
 Source: p.69 GE, 2009.
 : c RESOURCE_MANAGEMENT.D.Income.Frac = 0.80
 : s RESOURCE_MANAGEMENT.Total.ResD = 0
 : f RESOURCE_MANAGEMENT.Out.Total.ResD = RESOURCE_MANAGEMENT.Total.ResD
 : f RESOURCE_MANAGEMENT.In.Net.Fin.D =
 (RESOURCE_MANAGEMENT.D.Income.Frac*RESOURCE_MANAGEMENT.Out.Total.ResD)
 : f RESOURCE_MANAGEMENT.Out.Net.Fin.D = RESOURCE_MANAGEMENT.NetFin.ResD
 : c RESOURCE_MANAGEMENT.D2D.Reinv = 0.15
 : f RESOURCE_MANAGEMENT.In.D.Reinv =
 RESOURCE_MANAGEMENT.Out.Net.Fin.D*RESOURCE_MANAGEMENT.D2D.Reinv
 : c DEVELOPMENT.Kd = 1+RESOURCE_MANAGEMENT.Out.Govt.D+
 RESOURCE_MANAGEMENT.Out.VCtoD+RESOURCE_MANAGEMENT.In.D.Reinv
 : s RESOURCE_MANAGEMENT.Nat.Res.D = 10000000

DOCUMENT: Natural Resources are decreasing at a rate that will deplete these to half its current stock in 100 years.

```

: s RESOURCE_MANAGEMENT.Depletion_Rate = 2
DOCUMENT: Natural Resources are being depleted by many factors exogenous to biotech R&D. These resources are
being depleted at around 0.3% yearly and it is estimated that 1/3 of these will be gone in a century. However, these
biotech activities account for around 20% of the depleted resources yearly. Yet, through the application of biosafety
measures, the depletion rate accounted to R&D can be reduced overtime.
: c RESOURCE_MANAGEMENT.NRDep% = RESOURCE_MANAGEMENT.Depletion_Rate/100
: c RESOURCE_MANAGEMENT.Reg_Rate = 0.016
: f RESOURCE_MANAGEMENT.NatRes_Reg =
RESOURCE_MANAGEMENT.Nat_Res_D*RESOURCE_MANAGEMENT.Reg_Rate
: f RESOURCE_MANAGEMENT.NatRes_Dep =
RESOURCE_MANAGEMENT.Nat_Res_D*RESOURCE_MANAGEMENT.NRDep%
: f DEVELOPMENT.Input_D =
LOGN(DEVELOPMENT.HCd+DEVELOPMENT.Kd+RESOURCE_MANAGEMENT.NatRes_Dep)
: s DEVELOPMENT.Development_Potential = DEVELOPMENT.Input_D
: c DEVELOPMENT.Degree_HC = 60
: c DEVELOPMENT.HCt0 = DELAY(DEVELOPMENT.HCd,1)
: c DEVELOPMENT.ProbHC =
1+(DEVELOPMENT.Degree_HC+(DEVELOPMENT.Degree_HC*((DEVELOPMENT.HCd/DEVELOPMENT.HCt0)-1)))
: c DEVELOPMENT.ProbHC_Range =
IF DEVELOPMENT.ProbHC>100
THEN 100
ELSE DEVELOPMENT.ProbHC
: c DEVELOPMENT.MTCHC = MONTECARLO(DEVELOPMENT.ProbHC_Range)
: c DEVELOPMENT.Degree_K = 60
: c DEVELOPMENT.Kt0 = DELAY(DEVELOPMENT.Kd,1)
: c DEVELOPMENT.ProbK =
DEVELOPMENT.Degree_K+(DEVELOPMENT.Degree_K*((DEVELOPMENT.Kd/DEVELOPMENT.Kt0)-1))
: c DEVELOPMENT.ProbK_Range =
IF DEVELOPMENT.ProbK>100
THEN 100
ELSE DEVELOPMENT.ProbK
: c DEVELOPMENT.MTCK = MONTECARLO(DEVELOPMENT.ProbK_Range)
: c DEVELOPMENT.SUMAt1 = DEVELOPMENT.MTCHC+DEVELOPMENT.MTCK
: c DEVELOPMENT.SUMAt0 = DELAY(DEVELOPMENT.SUMAt1,1)
: c DEVELOPMENT.Tech_Advances = 1
: c DEVELOPMENT.i1Probability =
IF (DEVELOPMENT.SUMAt0<DEVELOPMENT.SUMAt1) OR (DEVELOPMENT.SUMAt0+DEVELOPMENT.SUMAt1=4)
THEN (DEVELOPMENT.Tech_Advances)
ELSE(0)
: f DEVELOPMENT.Successful_D = DEVELOPMENT.Development_Potential*DEVELOPMENT.i1Probability
: f DEVELOPMENT.Out_i1 = DEVELOPMENT.NDi1
: s INNOVATION_MANAGEMENT.Bio_Prob = 80
DOCUMENT: This is a Montecarlo probability that increases as the biosafety fund increases. The larger the probability,
the more probable a biotech product will reach the market.
: c INNOVATION_MANAGEMENT.Bio_Prob_Range =
IF INNOVATION_MANAGEMENT.Bio_Prob > 100
THEN 100
ELSE INNOVATION_MANAGEMENT.Bio_Prob
: c DEVELOPMENT.Bio_MCPProb = MONTECARLO(INNOVATION_MANAGEMENT.Bio_Prob_Range)
: s INNOVATION_MANAGEMENT.HS_Prob = 75
DOCUMENT: This is a Montecarlo probability that increases as the biosafety fund increases. The larger the probability,
the more probable a biotech product will reach the market.
: c INNOVATION_MANAGEMENT.HS_Prob_Range =
IF INNOVATION_MANAGEMENT.HS_Prob > 100

```

THEN 100
ELSE INNOVATION_MANAGEMENT.HS_Prob
: c DEVELOPMENT.HS_MCPProb = MONTECARLO(INNOVATION_MANAGEMENT.HS_Prob.Range)
: c DEVELOPMENT.Mkt.Prob =
IF (DEVELOPMENT.Bio_MCPProb+DEVELOPMENT.HS_MCPProb)=2
THEN 1
ELSE 0
DOCUMENT: Studies have found that only around 40% of the products developed reach the market level due to stringent regulatory requirements, which can be translated into an almost 40% chance per period that the developed product creates a new market. In this case biosafety and innocuous review procedures required by the government will create an indirect "tax" to the industry. Yet, this tax does not come back to the government but instead stays as a fund that increases (or decrease) the probability of approval as it changes.
One way of doing this is that in the case of the biosafety factor use the same procedure used for the change in the "Bio Effect" so that the Montecarlo probability changes overtime as the industry either pays more or less for biosafety requirements. This way the chance of being approved increases as a biosafety culture increases.
This also works for the Govt since the more production, the more the biosafety pay, and the less the natural resources are depleted (win-win situation).
: f DEVELOPMENT.To_Market = DEVELOPMENT.Out_i1*DEVELOPMENT.Mkt.Prob
DOCUMENT: Being this analysis from the POV of the central planner it is assumed that competing markets/ developers are constantly developing new innovations not withstanding those already in the market. The innovator/follower approach presented in the business management literature is overviewed.
: c RESOURCE_MANAGEMENT.eD2M = EXP(DEVELOPMENT.To_Market)
: c RESOURCE_MANAGEMENT.eTD2M =
IF RESOURCE_MANAGEMENT.eD2M = 1
THEN 0
ELSE RESOURCE_MANAGEMENT.eD2M
: c RESOURCE_MANAGEMENT.D.Price = 100
DOCUMENT: Assuming the transformed Knowledge is "x" as valuable the price of knowledge once it reaches the market as a product is "x." However, the PV of the income from these marketable products decreases at a fast pace since these become obsolete in a period of four years (suggested by the "Novelty Loss Rate") as these are replaced by new technologies. This also suggests that these are not completely worthless (zero value) whenever their is a new marketable product, based on the assumption that these still preserve some value at throughout the next three periods after their creation. Additionally, the price does not change over time since what changes is the demand for the actual innovation (again, it decreases linearly in a period of four years until it reaches a value of zero).
: c RESOURCE_MANAGEMENT.Inital.Income =
(DELAY(RESOURCE_MANAGEMENT.eTD2M,1))*RESOURCE_MANAGEMENT.D.Price
: c RESOURCE_MANAGEMENT.r = 0.03
: c RESOURCE_MANAGEMENT.FI1 =
(0.5*RESOURCE_MANAGEMENT.Inital.Income*((1+RESOURCE_MANAGEMENT.r)^(-1)))
DOCUMENT: This process means that whenever a product reaches the market, the developer gets three years of income. Yet, the level of this income decreases over time.
: c RESOURCE_MANAGEMENT.FI2 =
(0.25*RESOURCE_MANAGEMENT.FI1)*((1+RESOURCE_MANAGEMENT.r)^(-2))
: c RESOURCE_MANAGEMENT.FI3 =
(0.1*RESOURCE_MANAGEMENT.FI2)*((1+RESOURCE_MANAGEMENT.r)^(-3))
: c RESOURCE_MANAGEMENT.Capital.D =
RESOURCE_MANAGEMENT.Inital.Income+RESOURCE_MANAGEMENT.FI1+RESOURCE_MANAGEMENT.FI2+
RESOURCE_MANAGEMENT.FI3
DOCUMENT: In this case the capital that development produces is generated by the principal innovation (the rate that "To Market" produces at time "n") multiplied by the price, plus the present value of the returns that this principal will bring to the sector in the following three years before the innovation's market value reaches zero (the value loss is assumed to be 50% of the initial value after a year, 25% of that value at year two, 10% percent of that value are year three, and zero at year four). These figures are then summed at time "n."
: c RESOURCE_MANAGEMENT.Royalty_Level = 0.04
DOCUMENT: This level is considered a "running royalty" or percentage of the sale.

: c RESOURCE.MANAGEMENT.AnnD =
 (RESOURCE.MANAGEMENT.TeA1D*RESOURCE.MANAGEMENT.D.Price)*RESOURCE.MANAGEMENT.Royalty_Level

DOCUMENT: In the model, as happens in the information sector, there is no possible way of knowing beforehand if the use of the licensed IP will produce returns beforehand. The option considered here is an annuity of information/knowledge at current prices for the time the IPRs are enforceable. This is then brought to present value to produce the income to R from licensing.

: c RESOURCE.MANAGEMENT.AnnDPV =
 DEVELOPMENT.Mkt.Prob*PV(RESOURCE.MANAGEMENT.r,R&D.POLICY.Length,-RESOURCE.MANAGEMENT.AnnD,
 0)

DOCUMENT: This is the PV of an annuity of 0.04% of the principal (the figure found at time "n") for a period of 20 years if the product reaches the market (it has a probability of doing so of "Prob").That figure is added to the principal (the previous total Licensing Rate) at the time when it was found and brought to present value at time zero.

: c RESOURCE.MANAGEMENT.From.Licencing_D = RESOURCE.MANAGEMENT.AnnDPV

DOCUMENT: The amount of financial resources going back to research per period is composed by the actual licensing rate level at time "n" (which is valuate in Knowledge Units, A1) plus the present value (PV) of the annual royalty annuity from licensing at time "n" if the innovation reaches the market (this is why it is multiplied by "Prob").

: s R&D.POLICY.Biosafety_Level = 0.10

: c INNOVATION.MANAGEMENT.Y.Dev_Pay =
 IF NOT(RESOURCE.MANAGEMENT.Capital.D=0) AND RESOURCE.MANAGEMENT.Capital.D<1000
 THEN ((0.5*R&D.POLICY.Biosafety_Level)*RESOURCE.MANAGEMENT.Capital.D)
 ELSE R&D.POLICY.Biosafety_Level*RESOURCE.MANAGEMENT.Capital.D

: c INNOVATION.MANAGEMENT.N.Dev_Pay =
 IF RESOURCE.MANAGEMENT.Capital.D=0
 THEN (0*R&D.POLICY.Biosafety_Level*RESOURCE.MANAGEMENT.Capital.D)
 ELSE INNOVATION.MANAGEMENT.Y.Dev_Pay

: f INNOVATION.MANAGEMENT.In.Bio_Ind = INNOVATION.MANAGEMENT.N.Dev_Pay

: s R&D.POLICY.Health_Safe_Rate = 0.15

: c INNOVATION.MANAGEMENT.Y.Dev_HS_Pay =
 IF NOT(RESOURCE.MANAGEMENT.Capital.D=0) AND RESOURCE.MANAGEMENT.Capital.D<1000
 THEN (0.5*R&D.POLICY.Health_Safe_Rate*RESOURCE.MANAGEMENT.Capital.D)
 ELSE RESOURCE.MANAGEMENT.Capital.D*R&D.POLICY.Health_Safe_Rate

: c INNOVATION.MANAGEMENT.N.Dev_HS_Pay =
 IF (RESOURCE.MANAGEMENT.Capital.D=0)
 THEN (0*R&D.POLICY.Health_Safe_Rate*RESOURCE.MANAGEMENT.Capital.D)
 ELSE INNOVATION.MANAGEMENT.Y.Dev_HS_Pay

: f INNOVATION.MANAGEMENT.In_HS_Fund = INNOVATION.MANAGEMENT.N.Dev_HS_Pay

: c RESOURCE.MANAGEMENT.PreTax_Kd =
 (((RESOURCE.MANAGEMENT.Capital.D-RESOURCE.MANAGEMENT.From.Licencing_D)-
 INNOVATION.MANAGEMENT.In.Bio_Ind)-INNOVATION.MANAGEMENT.In_HS_Fund)

: s R&D.POLICY.Tax_Rate = 0.35

: c RESOURCE.MANAGEMENT.Fiscal_InD =
 IF RESOURCE.MANAGEMENT.PreTax_Kd <0
 THEN 0
 ELSE RESOURCE.MANAGEMENT.PreTax_Kd*R&D.POLICY.Tax_Rate

: c RESOURCE.MANAGEMENT.Royalty_Rule = 1

: s RESOURCE.MANAGEMENT.TechT_RtoD = 0

: f RESOURCE.MANAGEMENT.In.TT_from_D = RESOURCE.MANAGEMENT.From.Licencing_D

DOCUMENT: TTF= Technology transfer funds from development to research derived from licensing.

: f RESOURCE.MANAGEMENT.Out.TT_From_D = RESOURCE.MANAGEMENT.TechT_RtoD

DOCUMENT: This fraction is due to the patent regulation existing in Spain operating in a similar way to the Bayh-Dole act requiring this allocation of resources between these three elements. It is assumed that this income division only affects the licensing of patents to research, since these are mostly funded by government and the information necessary for these is developed within public research centers. The "Royalty Rule" switch is introduced to differentiate the model's approach for Mexico -which does not have such rule- from that of Spain.

: c RESOURCE.MANAGEMENT.TTD_Frac = 0.333

DOCUMENT: See the Document in “Out TTF From D” for an explanation to this fraction.

```

: f RESOURCE.MANAGEMENT.TTRD_to_Govt =
IF RESOURCE.MANAGEMENT.Royalty_Rule = 1
THEN (RESOURCE.MANAGEMENT.Out_TT_From_D*RESOURCE.MANAGEMENT.TTD_Frac)
ELSE 0
: c INNOVATION.MANAGEMENT.Biosafety_Review_Costs = 100000
: f INNOVATION.MANAGEMENT.Bio_Ind_to_Govt =
IF DEVELOPMENT.Successful_D > 0
THEN INNOVATION.MANAGEMENT.Biosafety_Review_Costs
ELSE 0
: s RESOURCE.MANAGEMENT.R_Save = 0
: s RESOURCE.MANAGEMENT.R_Income = 0
: f RESOURCE.MANAGEMENT.TTRD_to_R =
IF RESOURCE.MANAGEMENT.Royalty_Rule = 1
THEN (RESOURCE.MANAGEMENT.Out_TT_From_D*RESOURCE.MANAGEMENT.TTD_Frac)
ELSE RESOURCE.MANAGEMENT.Out_TT_From_D*0.8
: s RESOURCE.MANAGEMENT.TechT_RtoR = 0
: c RESOURCE.MANAGEMENT.AnnR =
(RESOURCE.MANAGEMENT.TeA1R*RESOURCE.MANAGEMENT.D_Price)*
RESOURCE.MANAGEMENT.Royalty_Level
: c RESOURCE.MANAGEMENT.AnnRPV =
INNOVATION.MANAGEMENT.Match_Type_2*
PV(RESOURCE.MANAGEMENT.r, R&D_POLICY.Length, -RESOURCE.MANAGEMENT.AnnR, 0)
: c RESOURCE.MANAGEMENT.From_Licensing_R = RESOURCE.MANAGEMENT.AnnRPV
: f RESOURCE.MANAGEMENT.In_TT_from_R = RESOURCE.MANAGEMENT.From_Licensing_R
: f RESOURCE.MANAGEMENT.Out_TT_From_R = RESOURCE.MANAGEMENT.TechT_RtoR
: c RESOURCE.MANAGEMENT.TTF_R_Fraction = 0.95
: f RESOURCE.MANAGEMENT.TTTR_To_R =
RESOURCE.MANAGEMENT.Out_TT_From_R*RESOURCE.MANAGEMENT.TTF_R_Fraction
: f RESOURCE.MANAGEMENT.In_ResR =
(RESOURCE.MANAGEMENT.TTRD_to_R+RESOURCE.MANAGEMENT.TTTR_To_R)
: f RESOURCE.MANAGEMENT.Out_NetFinR =
RESOURCE.MANAGEMENT.NetFin_ResR
: f RESOURCE.MANAGEMENT.In_R_Inc =
RESOURCE.MANAGEMENT.Out_NetFinR
: f RESOURCE.MANAGEMENT.Out_R_Inc =
RESOURCE.MANAGEMENT.R_Income
: c RESOURCE.MANAGEMENT.Save_Rate = 0.25
: f RESOURCE.MANAGEMENT.In_R_Save =
RESOURCE.MANAGEMENT.Out_R_Inc*RESOURCE.MANAGEMENT.Save_Rate
: f RESOURCE.MANAGEMENT.Out_R_Save = RESOURCE.MANAGEMENT.R_Save
DOCUMENT: These are assumed to be resources going back to the government that originally provide them.
: s RESOURCE.MANAGEMENT.Risk_Free_Comp = 1
DOCUMENT: This means these funds are invested in government bonds, thus, going back to the government resources.
: f RESOURCE.MANAGEMENT.In_Res_Govt =
IF RESOURCE.MANAGEMENT.FixR&D_Fund_Switch = 1
THEN (RESOURCE.MANAGEMENT.FixedGovt_Fund+
(RESOURCE.MANAGEMENT.Fiscal_InD+RESOURCE.MANAGEMENT.TTRD_to_Govt+
INNOVATION.MANAGEMENT.Bio_Ind_to_Govt+RESOURCE.MANAGEMENT.Out_R_Save+
RESOURCE.MANAGEMENT.Risk_Free_Comp))
ELSE RESOURCE.MANAGEMENT.Fiscal_InD+RESOURCE.MANAGEMENT.TTRD_to_Govt+
INNOVATION.MANAGEMENT.Bio_Ind_to_Govt+RESOURCE.MANAGEMENT.Out_R_Save+
RESOURCE.MANAGEMENT.Risk_Free_Comp
: f RESOURCE.MANAGEMENT.Out_Res_Govt = RESOURCE.MANAGEMENT.Net_Res_Govt
: s R&D.POLICY.R&D_Rate = 0.84

```

DOCUMENT: This rate comes from p.32 in the 2009 GE report.

```

: f RESOURCE_MANAGEMENT.In.Govt.R = RESOURCE_MANAGEMENT.Out.Res.Govt*R&D.POLICY.R&D.Rate
: f RESOURCE_MANAGEMENT.Out.Govt.R = RESOURCE_MANAGEMENT.Govt.R
: s RESOURCE_MANAGEMENT.VCtoR = 0
: f RESOURCE_MANAGEMENT.Out.VCtoR = RESOURCE_MANAGEMENT.VCtoR
: c RESEARCH.Kr = 1+RESOURCE_MANAGEMENT.Out.Govt.R+RESOURCE_MANAGEMENT.Out.VCtoR
DOCUMENT: K is multiplied by a fraction of A1 (information) because information is capital. In this example each unit
of capital is worth two units of information.
: s RESOURCE_MANAGEMENT.Gene.Res = 10000000
: s RESOURCE_MANAGEMENT.GeneDep.Rate = 2
DOCUMENT: Genetic Resources are being depleted by biotech R&D. In the model these resources are being prospected
at around 0.3% yearly and it is estimated that 1/3 of these will be protected by IPRs in a century. Biotech activities
account for the entire genetic resource erosion. Yet, through less secluding IPR measures, access to the information
generated by these resources can be increased overtime.
: c RESOURCE_MANAGEMENT.GRDep% = RESOURCE_MANAGEMENT.GeneDep.Rate/100
: c RESOURCE_MANAGEMENT.Gene.Prospect = 0.02
: f RESOURCE_MANAGEMENT.In.Gene.Res = RESOURCE_MANAGEMENT.Gene.Res*
RESOURCE_MANAGEMENT.Gene.Prospect
: f RESOURCE_MANAGEMENT.Out.Gene.Res = RESOURCE_MANAGEMENT.Gene.Res*
RESOURCE_MANAGEMENT.GRDep%
: f RESEARCH.Input.R = LOGN(RESEARCH.HCr+RESEARCH.Kr+RESOURCE_MANAGEMENT.Out.Gene.Res)
: s RESEARCH.Research.Potential = RESEARCH.Input.R
: f RESEARCH.Output.R = RESEARCH.Research.Potential
: f DEVELOPMENT.Output.D = DEVELOPMENT.Development.Potential
: s RESOURCE_MANAGEMENT.Biotech.Labor = 1000
DOCUMENT: 100
: c RESOURCE_MANAGEMENT.D.Rate = 0.01987
: c RESOURCE_MANAGEMENT.G.Rate = 0.02
: f RESOURCE_MANAGEMENT.In.BioLab = RESOURCE_MANAGEMENT.Biotech.Labor*
RESOURCE_MANAGEMENT.G.Rate
: f RESOURCE_MANAGEMENT.Out.BioLab = RESOURCE_MANAGEMENT.Biotech.Labor*
RESOURCE_MANAGEMENT.D.Rate
: s INNOVATION_MANAGEMENT.Bio.Ind.Res = 10000000
DOCUMENT: Biosafety pertains to preserving the balance of natural resources. In the model it focuses on prevent-
ing over depleting natural resources. The access to genetic resources, as related to the access and management of
information derived from genetic resources, is considered within its own subsystem. In this sense, development deals
exclusively with biosafety, while research deals exclusively with the access to genetic resources.
It is only in the realm of development because it deals with the protection of natural resources from the effects of devel-
oped technologies, like LGMOs freed to the environment for experimental, trail, or commercial reasons. Research, on
the other hand, deals with extracting basic information from a particular natural resource type in the form of genes or
genetic resources.
: c RESOURCE_MANAGEMENT.Bio.Effect.Change = 0.05
: c RESOURCE_MANAGEMENT.Dev.Effect5 =
IF NOT(INNOVATION_MANAGEMENT.Bio.Ind.Res>5000000) AND INNOVATION_MANAGEMENT.Bio.Ind.Res
> 1000000
THEN 0.01*RESOURCE_MANAGEMENT.Bio.Effect.Change
ELSE 0
: c RESOURCE_MANAGEMENT.Dev.Effect4 =
IF NOT(INNOVATION_MANAGEMENT.Bio.Ind.Res>8500000) AND INNOVATION_MANAGEMENT.Bio.Ind.Res
> 5000000
THEN 0.1*RESOURCE_MANAGEMENT.Bio.Effect.Change
ELSE RESOURCE_MANAGEMENT.Dev.Effect5
: c RESOURCE_MANAGEMENT.Dev.Effect3 =
IF NOT (INNOVATION_MANAGEMENT.Bio.Ind.Res>9000000) AND INNOVATION_MANAGEMENT.Bio.Ind.Res
> 8500000

```

```

THEN RESOURCE_MANAGEMENT.Bio_Effect_Change*0.25
ELSE RESOURCE_MANAGEMENT.Dev_Effect4
: c RESOURCE_MANAGEMENT.Dev_Effect2 =
IF NOT (INNOVATION_MANAGEMENT.Bio_Ind_Res>10000000 OR INNOVATION_MANAGEMENT.Bio_Ind_Res=0)
AND INNOVATION_MANAGEMENT.Bio_Ind_Res>9000000
THEN RESOURCE_MANAGEMENT.Bio_Effect_Change*0.5
ELSE RESOURCE_MANAGEMENT.Dev_Effect3
: c RESOURCE_MANAGEMENT.Dev_Effect1 =
IF INNOVATION_MANAGEMENT.Bio_Ind_Res >10000000
THEN RESOURCE_MANAGEMENT.Bio_Effect_Change
ELSE RESOURCE_MANAGEMENT.Dev_Effect2
: c RESOURCE_MANAGEMENT.Dev_Effect0 =
IF INNOVATION_MANAGEMENT.Bio_Ind_Res =0
THEN RESOURCE_MANAGEMENT.Bio_Effect_Change*INNOVATION_MANAGEMENT.Bio_Ind_Res
ELSE RESOURCE_MANAGEMENT.Dev_Effect1
: c RESOURCE_MANAGEMENT.If_Change =
IF RESOURCE_MANAGEMENT.Dev_Effect0 >0
THEN RESOURCE_MANAGEMENT.Dev_Effect0
ELSE 0
: c RESOURCE_MANAGEMENT.If_No_Change = 0.02
: f RESOURCE_MANAGEMENT.In_DR =
IF RESOURCE_MANAGEMENT.If_Change>0
THEN RESOURCE_MANAGEMENT.Depletion_Rate-RESOURCE_MANAGEMENT.If_Change
ELSE RESOURCE_MANAGEMENT.Depletion_Rate+RESOURCE_MANAGEMENT.If_No_Change
DOCUMENT: If there are no "Biosafety Industry Resources" then depletion "Factor" increases 0.05, if "BIR" is positive
within a range then "Factor" decreases (depending on the level: 0<BIR<1000 then the "Bio Effect Change" (0.5) is al-
tered by either a factor of 50%, 25%, 10%, or 0).
: f RESOURCE_MANAGEMENT.Out_DR = RESOURCE_MANAGEMENT.Depletion_Rate
: s RESOURCE_MANAGEMENT.BR_Infra_Res = 0
DOCUMENT: Public Infrastructure is endowed with a 100,000 monetary units at t0. It is assumed that there is an initial
infrastructure of 10 research centers each worth 10,000 monetary units. Public infrastructure, however, depreciates at a
linear rate of 0.025 per period.
: f RESOURCE_MANAGEMENT.TTRD_to_R_Infra =
IF RESOURCE_MANAGEMENT.Royalty_Rule=1
THEN (RESOURCE_MANAGEMENT.Out_TT_From_D*RESOURCE_MANAGEMENT.TTD_Frac)
ELSE RESOURCE_MANAGEMENT.Out_TT_From_D*0.20
: f RESOURCE_MANAGEMENT.TTRR_To_R_Infra =
RESOURCE_MANAGEMENT.Out_TT_From_R*(1-RESOURCE_MANAGEMENT.TTF_R_Fraction)
: s RESOURCE_MANAGEMENT.Govt_Infra = 0
DOCUMENT: See the documents in the other two funds.
: s R&D.POLICY.Infra_Rate = 0.1
DOCUMENT: This rate comes from an approximation from p. 32 of the GE 2009 report.
: f RESOURCE_MANAGEMENT.In_Govt_Infra = RESOURCE_MANAGEMENT.Out_Res.Govt*R&D.POLICY.Infra_Rate
: f RESOURCE_MANAGEMENT.Out_Govt_Infra = RESOURCE_MANAGEMENT.Govt_Infra
: f RESOURCE_MANAGEMENT.In_BR_Infra = (RESOURCE_MANAGEMENT.TTRD_to_R_Infra+
RESOURCE_MANAGEMENT.TTRR_To_R_Infra+RESOURCE_MANAGEMENT.Out_Govt_Infra)
: f RESOURCE_MANAGEMENT.Out_BR_Infra = RESOURCE_MANAGEMENT.BR_Infra_Res
: s RESOURCE_MANAGEMENT.D_Income = 0
: f RESOURCE_MANAGEMENT.In_D_Inc = RESOURCE_MANAGEMENT.Out_Net_FIn_D-
RESOURCE_MANAGEMENT.In_D_Reinv
: f RESOURCE_MANAGEMENT.Out_D_Inc = RESOURCE_MANAGEMENT.D_Income
: s RESOURCE_MANAGEMENT.D_Reinvest = 0
: f RESOURCE_MANAGEMENT.Out_D_Reinv = RESOURCE_MANAGEMENT.D_Reinvest
: s RESOURCE_MANAGEMENT.VCRD_Bal = 0
: s RESOURCE_MANAGEMENT.VCR_Fund = 0

```

DOCUMENT: This fund is composed by the surplus generated when there is a surplus after paying investors the amount these allocated for VC. It can also be negative when either R or D are not successful.

: s RESOURCE_MANAGEMENT.VCtoR.Debt = 0

DOCUMENT: There is a need to coordinate the payment of this VC debt with the funds set to do so.

: c RESOURCE_MANAGEMENT.Dif.VCR_Res =

RESOURCE_MANAGEMENT.VCR_Fund-RESOURCE_MANAGEMENT.VCtoR.Debt

: f RESOURCE_MANAGEMENT.In.VCRD_Bal =

IF RESOURCE_MANAGEMENT.Dif.VCR_Res<0

THEN (-1*RESOURCE_MANAGEMENT.Dif.VCR_Res)

ELSE 0

: f RESOURCE_MANAGEMENT.Out.VCRD_Bal = RESOURCE_MANAGEMENT.VCRD_Bal

: s RESOURCE_MANAGEMENT.VCRF_Bal = 0

: f RESOURCE_MANAGEMENT.In.VCRF_Bal = RESOURCE_MANAGEMENT.Dif.VCR_Res

: f RESOURCE_MANAGEMENT.Out.VCRF_Bal = RESOURCE_MANAGEMENT.VCRF_Bal

: s RESOURCE_MANAGEMENT.D.Spend = 0

DOCUMENT: This should be connected to the "To Market" level in order to buy out all products at the price level. Once there are no more "X Spending" resources the income ends. Check is this can be done. Remember, this will set the price level and the success of the product in the market.

Figure a way to measure that every individual consumes the product.

: f RESOURCE_MANAGEMENT.In.D_Save =

RESOURCE_MANAGEMENT.Out.D.Inc*RESOURCE_MANAGEMENT.Save_Rate

: f RESOURCE_MANAGEMENT.In.D_Spend =

RESOURCE_MANAGEMENT.Out.D.Inc-RESOURCE_MANAGEMENT.In.D_Save

: f RESOURCE_MANAGEMENT.Out.D_Spend = RESOURCE_MANAGEMENT.D.Spend

: s RESOURCE_MANAGEMENT.D_Save = 0

: f RESOURCE_MANAGEMENT.Out.D_Save = RESOURCE_MANAGEMENT.D_Save

: s RESOURCE_MANAGEMENT.R.Spend = 0

: f RESOURCE_MANAGEMENT.In.R_Spend =

RESOURCE_MANAGEMENT.Out.R.Inc-RESOURCE_MANAGEMENT.In.R_Save

: f RESOURCE_MANAGEMENT.Out.R_Spend = RESOURCE_MANAGEMENT.R.Spend

: s RESOURCE_MANAGEMENT.All.Spend = 0

: f RESOURCE_MANAGEMENT.In.Spend =

RESOURCE_MANAGEMENT.Out.D.Spend+RESOURCE_MANAGEMENT.Out.R_Spend

: f RESOURCE_MANAGEMENT.Out.Spend = RESOURCE_MANAGEMENT.All.Spend

: s RESOURCE_MANAGEMENT.All.Save = 0

: f RESOURCE_MANAGEMENT.In_Save =

RESOURCE_MANAGEMENT.Out.R_Save+RESOURCE_MANAGEMENT.Out.D_Save

: f RESOURCE_MANAGEMENT.To_Invest = RESOURCE_MANAGEMENT.All_Save

: s RESOURCE_MANAGEMENT.RtoD.%Mob = 0.77

: c RESOURCE_MANAGEMENT.Change.%LR = 0.01

: c RESOURCE_MANAGEMENT.RtoD2 =

IF RESOURCE_MANAGEMENT.Available_Lr < INNOVATION_MANAGEMENT.R.Infra.L.Capacity

THEN (+1*RESOURCE_MANAGEMENT.Change.%LR)

ELSE 0

: c RESOURCE_MANAGEMENT.RtoD1 =

IF RESOURCE_MANAGEMENT.Available_Lr > INNOVATION_MANAGEMENT.R.Infra.L.Capacity

THEN (-1*RESOURCE_MANAGEMENT.Change.%LR)

ELSE RESOURCE_MANAGEMENT.RtoD2

: c RESOURCE_MANAGEMENT.RtoD_Arbit =

IF RESOURCE_MANAGEMENT.Available_Lr = INNOVATION_MANAGEMENT.R.Infra.L.Capacity

THEN 0

ELSE RESOURCE_MANAGEMENT.RtoD1

: f RESOURCE_MANAGEMENT.In.RD%Mob =

RESOURCE_MANAGEMENT.RtoD_Arbit+RESOURCE_MANAGEMENT.RtoD.%Mob

: f RESOURCE_MANAGEMENT.Out.RD%Mob = RESOURCE_MANAGEMENT.RtoD.%Mob

```

: s RESOURCE_MANAGEMENT.Risk_Free_Inv = 0
: c RESOURCE_MANAGEMENT.VC_Switch = 1
: c RESOURCE_MANAGEMENT.Invest_Rule_YVC = RESOURCE_MANAGEMENT.To_Invest
: c RESOURCE_MANAGEMENT.VC% = 0.15
: c RESOURCE_MANAGEMENT.VC_Change =
IF RESOURCE_MANAGEMENT.Out_VCtoR>0 OR RESOURCE_MANAGEMENT.Out_VCtoD>0
THEN (RESOURCE_MANAGEMENT.VC%+0.01)
ELSE (RESOURCE_MANAGEMENT.VC%-0.001)
: c RESOURCE_MANAGEMENT.VC_Invest = RESOURCE_MANAGEMENT.VC_Change
DOCUMENT: This is the percentage of the total To Investment rate that goes to VC instead of Risk Free Investment.
: f RESOURCE_MANAGEMENT.To_VC =
IF RESOURCE_MANAGEMENT.VC_Switch=1
THEN (RESOURCE_MANAGEMENT.Invest_Rule_YVC*RESOURCE_MANAGEMENT.VC_Invest)
ELSE 0
: c RESOURCE_MANAGEMENT.Invest_Rule_NVC = RESOURCE_MANAGEMENT.To_Invest
: f RESOURCE_MANAGEMENT.To_Risk_Free =
IF RESOURCE_MANAGEMENT.VC_Switch=1
THEN (RESOURCE_MANAGEMENT.Invest_Rule_YVC-RESOURCE_MANAGEMENT.To_VC)
ELSE RESOURCE_MANAGEMENT.Invest_Rule_NVC
: f RESOURCE_MANAGEMENT.To_Compound =
RESOURCE_MANAGEMENT.Risk_Free_Inv+RESOURCE_MANAGEMENT.Risk_Free_Comp*
CGROWTH((100*RESOURCE_MANAGEMENT.r))
: c RESOURCE_MANAGEMENT.Kr_Delay = DELAY(RESEARCH.Kr,1)
: c RESOURCE_MANAGEMENT.VCR =
IF RESOURCE_MANAGEMENT.NetFin_ResR>(RESOURCE_MANAGEMENT.Kr_Delay*RESOURCE_MANAGEMENT.r)
THEN 1
ELSE 0
DOCUMENT: Here, VC investors will risk their resources if the levels of income display by the sector are above those
that the natural interest rate would offer, meaning they will be able to collect at least as much as they would if they
were investing on risk free options (instead of having "IF Net_Financial_Resources_(R,D) > Kr_Delay (5) THEN 1 ELSE
0, comparing the net returns today with investment levels five years ago).
: c RESOURCE_MANAGEMENT.Kd_Delay = DELAY(DEVELOPMENT.Kd,1)
: c RESOURCE_MANAGEMENT.VCD =
IF RESOURCE_MANAGEMENT.NetFin_ResD>(RESOURCE_MANAGEMENT.Kd_Delay*RESOURCE_MANAGEMENT.r)
THEN 1
ELSE 0
: c RESOURCE_MANAGEMENT.VC4 =
IF RESOURCE_MANAGEMENT.VCR=0 AND RESOURCE_MANAGEMENT.VCD=0
THEN 1
ELSE 0
: c RESOURCE_MANAGEMENT.VC3 =
IF RESOURCE_MANAGEMENT.VCD=0 AND RESOURCE_MANAGEMENT.VCR=1
THEN 2
ELSE RESOURCE_MANAGEMENT.VC4
: c RESOURCE_MANAGEMENT.VC2 =
IF RESOURCE_MANAGEMENT.VCR=0 AND RESOURCE_MANAGEMENT.VCD = 1
THEN 3
ELSE RESOURCE_MANAGEMENT.VC3
: c RESOURCE_MANAGEMENT.VC1 =
IF RESOURCE_MANAGEMENT.VCR AND RESOURCE_MANAGEMENT.VCD = 1
THEN 4
ELSE RESOURCE_MANAGEMENT.VC2
: s RESOURCE_MANAGEMENT.VC_Total = 90000000
DOCUMENT: Venture Capital is a fraction of all savings from both research and development activities. This fraction
changes over time depending on its performance. It becomes invested in either research or development depending on

```

the performance of capital spending in either sector (when VC1 = 2, it goes to R; when VC1 = 3, it goes to D; when VC1 = 4, it is spread evenly between the two; when VC1=1, it remains stocked); to decide this, capital investment (Kr or Kd) is compared to the Net Financial Resources of each sector. Whenever the NFR(r,d) of either sector is larger than the capital investment K (r,d) at any time, investors decide to invest in the sector. In the case when capital investment of either sector is less than its NFR venture capital is stocked until either sector displays larger NFR than K. The model, however, does not allow for both sectors to perform successfully simultaneously, meaning that $NFR > Kr$ and $NFR > Kd$ can not simultaneously exist. Original level 120m.

: c RESOURCE_MANAGEMENT.VC.Invest.Rate = 0.25

DOCUMENT: This is the amount (%) of the VC Total stock that gets invested each time.

: f RESOURCE_MANAGEMENT.Out.VC =

IF (RESOURCE_MANAGEMENT.VC1=4

OR RESOURCE_MANAGEMENT.VC1=3

OR RESOURCE_MANAGEMENT.VC1=2) AND RESOURCE_MANAGEMENT.VC.Switch=1

THEN (RESOURCE_MANAGEMENT.VC.Total*RESOURCE_MANAGEMENT.VC.Invest.Rate)

ELSE 0

: c RESOURCE_MANAGEMENT.From.VCRD.Bal = RESOURCE_MANAGEMENT.In.VCRD.Bal

DOCUMENT: This parameter represents the amount of the following:

: f RESOURCE_MANAGEMENT.In.VCR.Debt =

RESOURCE_MANAGEMENT.Out.VCtoR+RESOURCE_MANAGEMENT.From.VCRD.Bal

: f RESOURCE_MANAGEMENT.Out.VCR.Debt = RESOURCE_MANAGEMENT.VCtoR.Debt

: s RESOURCE_MANAGEMENT.VCtoD.Debt = 0

: s RESOURCE_MANAGEMENT.VCD.Fund = 0

: c RESOURCE_MANAGEMENT.Dif.VCD.Res =

RESOURCE_MANAGEMENT.VCD.Fund-RESOURCE_MANAGEMENT.VCtoD.Debt

: f RESOURCE_MANAGEMENT.In.VCDD.Bal =

IF RESOURCE_MANAGEMENT.Dif.VCD.Res<0

THEN (-1*RESOURCE_MANAGEMENT.Dif.VCD.Res)

ELSE 0

: c RESOURCE_MANAGEMENT.From.VCDD.Bal = RESOURCE_MANAGEMENT.In.VCDD.Bal

: f RESOURCE_MANAGEMENT.In.VCD.Debt =

RESOURCE_MANAGEMENT.Out.VCtoD+RESOURCE_MANAGEMENT.From.VCDD.Bal

: f RESOURCE_MANAGEMENT.Out.VCD.Debt = RESOURCE_MANAGEMENT.VCtoD.Debt

: c RESOURCE_MANAGEMENT.D.Debt.Rate = 0.05

: f RESOURCE_MANAGEMENT.In.VCDF.Bal = RESOURCE_MANAGEMENT.Dif.VCD.Res

: c RESOURCE_MANAGEMENT.From.VCDF.Bal = RESOURCE_MANAGEMENT.In.VCDF.Bal

: f RESOURCE_MANAGEMENT.In.VCD.Fund =

(RESOURCE_MANAGEMENT.In.D.Inc*RESOURCE_MANAGEMENT.D.Debt.Rate)+

RESOURCE_MANAGEMENT.From.VCDF.Bal

DOCUMENT: The figure represented by the debt rate times the Income represents the amount of financial resources available to support VC investment, it is not an actual capital flow (reason why these are not actually discounted from the inflow of income coming to either R or D). The actual physical resources are those coming from the VCR and VCD funds balance.

: f RESOURCE_MANAGEMENT.Out.VCD.Fund = RESOURCE_MANAGEMENT.VCD.Fund

: c RESOURCE_MANAGEMENT.R.Debt.Rate = 0.15

: c RESOURCE_MANAGEMENT.From.VCRF.Bal = RESOURCE_MANAGEMENT.In.VCRF.Bal

: f RESOURCE_MANAGEMENT.In.VCR.Fund =

(RESOURCE_MANAGEMENT.R.Debt.Rate*RESOURCE_MANAGEMENT.In.R.Inc)+

RESOURCE_MANAGEMENT.From.VCRF.Bal

DOCUMENT: Debt rate is the maximum amount of income allowed to be allocated towards paying debt. In other words is the maximum leverage level that the sector can leverage its income.

: f RESOURCE_MANAGEMENT.Out.VCR.Fund = RESOURCE_MANAGEMENT.VCR.Fund

: s RESOURCE_MANAGEMENT.VCDD.Bal = 0

: f RESOURCE_MANAGEMENT.Out.VCDD.Bal = RESOURCE_MANAGEMENT.VCDD.Bal

: s RESOURCE_MANAGEMENT.VCDF.Bal = 0

: f RESOURCE_MANAGEMENT.Out.VCDF.Bal = RESOURCE_MANAGEMENT.VCDF.Bal

```

: s RESOURCE_MANAGEMENT.Intl_VC_Fund = 100000000
: c RESOURCE_MANAGEMENT.Intl_VC_Invest_Rate = 0.1
: c RESOURCE_MANAGEMENT.Out_Restriction =
IF NOT (RESOURCE_MANAGEMENT.VC1=2
OR RESOURCE_MANAGEMENT.VC1=3
OR RESOURCE_MANAGEMENT.VC1=4)
THEN 0
ELSE 1
DOCUMENT: This restriction allows the flow of VC into projects only when the matching mechanism is available. In
other words, only when VC1 is equal to 2, 3 or 4 and not when there is no match, as in VC1=1.
: c RESOURCE_MANAGEMENT.Intl_VC_Invest = 100000
: f RESOURCE_MANAGEMENT.In_Intl_VC = RESOURCE_MANAGEMENT.Intl_VC_Invest
: f RESOURCE_MANAGEMENT.Out_Intl_VC =
(RESOURCE_MANAGEMENT.Intl_VC_Fund*RESOURCE_MANAGEMENT.Intl_VC_Invest_Rate)*
RESOURCE_MANAGEMENT.Out_Restriction
: c RESEARCH.Degree_HC = 40
: c RESEARCH.HCt0 = DELAY(RESEARCH.HCr,1)
: c RESEARCH.ProbHC =
(RESEARCH.Degree_HC+(RESEARCH.Degree_HC*((RESEARCH.HCr/RESEARCH.HCt0)-1)))
: c RESEARCH.ProbHC_Range =
IF RESEARCH.ProbHC>100
THEN 100
ELSE RESEARCH.ProbHC
: c RESEARCH.MTCHCr = MONTECARLO(RESEARCH.ProbHC_Range)
: c RESEARCH.Degree_K = 40
: c RESEARCH.Kt0 = DELAY(RESEARCH.Kr,1)
: c RESEARCH.ProbK =
(RESEARCH.Degree_K+(RESEARCH.Degree_K*((RESEARCH.Kr/RESEARCH.Kt0)-1)))
: c RESEARCH.ProbK_Range =
IF RESEARCH.ProbK>100
THEN 100
ELSE RESEARCH.ProbK
DOCUMENT: This step is to maintain the 0 to 100 change range within the Montecarlo probability. Some of the values
are beyond 100 and, thus, have to be standardized within the range.
: c RESEARCH.MTCKr = MONTECARLO(RESEARCH.ProbK_Range)
: c RESEARCH.SUMAt1 = RESEARCH.MTCHCr+RESEARCH.MTCKr
: c RESEARCH.SUMAt0 = DELAY(RESEARCH.SUMAt1,1)
: c RESEARCH.Tech_Advances = 1
: c RESEARCH.A1Probability =
IF (RESEARCH.SUMAt0<RESEARCH.SUMAt1)
OR (RESEARCH.SUMAt0+RESEARCH.SUMAt1=4)
THEN (RESEARCH.Tech_Advances)
ELSE 0
: f RESEARCH.Successful_R = RESEARCH.Research_Potential*RESEARCH.A1Probability
: c RESOURCE_MANAGEMENT.eSuccess_R = EXP(RESEARCH.Successful_R)
: c RESOURCE_MANAGEMENT.Access_Gene_Res = 0.1
: s R&D.POLICY.Breadth_Fact = 0.5
: c RESOURCE_MANAGEMENT.Gene_Effect_Change =
RESOURCE_MANAGEMENT.Access_Gene_Res*R&D.POLICY.Breadth_Fact
: c RESOURCE_MANAGEMENT.R_Effect5 =
IF NOT(RESOURCE_MANAGEMENT.eSuccess_R>1000000) AND RESOURCE_MANAGEMENT.eSuccess_R > 1
THEN 0.01*RESOURCE_MANAGEMENT.Gene_Effect_Change
ELSE 0
: c RESOURCE_MANAGEMENT.R_Effect4 =
IF NOT(RESOURCE_MANAGEMENT.eSuccess_R>2000000) AND RESOURCE_MANAGEMENT.eSuccess_R > 1000000

```

```

THEN 0.1*RESOURCE.MANAGEMENT.Gene_Effect_Change
ELSE RESOURCE.MANAGEMENT.R.Effect5
: c RESOURCE.MANAGEMENT.R.Effect3 =
IF NOT (RESOURCE.MANAGEMENT.eSuccess_R>5000000) AND RESOURCE.MANAGEMENT.eSuccess_R >
2000000
THEN RESOURCE.MANAGEMENT.Gene_Effect_Change*0.25
ELSE RESOURCE.MANAGEMENT.R.Effect4
: c RESOURCE.MANAGEMENT.R.Effect2 =
IF NOT( RESOURCE.MANAGEMENT.eSuccess_R>10000000
OR RESOURCE.MANAGEMENT.eSuccess_R=0) AND RESOURCE.MANAGEMENT.eSuccess_R>5000000
THEN RESOURCE.MANAGEMENT.Gene_Effect_Change*0.5
ELSE RESOURCE.MANAGEMENT.R.Effect3
: c RESOURCE.MANAGEMENT.R.Effect1 =
IF RESOURCE.MANAGEMENT.eSuccess_R >10000000
THEN RESOURCE.MANAGEMENT.Gene_Effect_Change
ELSE RESOURCE.MANAGEMENT.R.Effect2
: c RESOURCE.MANAGEMENT.R.Effect0 =
IF RESOURCE.MANAGEMENT.eSuccess_R =0
THEN RESOURCE.MANAGEMENT.Gene_Effect_Change*RESOURCE.MANAGEMENT.eSuccess_R
ELSE RESOURCE.MANAGEMENT.R.Effect1
: c RESOURCE.MANAGEMENT.If_R_Change =
IF RESOURCE.MANAGEMENT.R.Effect0 >0
THEN RESOURCE.MANAGEMENT.R.Effect0
ELSE 0
: c RESOURCE.MANAGEMENT.If_No_R_Change = 0.02
: f RESOURCE.MANAGEMENT.In_GR_Dep =
IF RESOURCE.MANAGEMENT.If_R_Change>0
THEN RESOURCE.MANAGEMENT.GeneDep_Rate-RESOURCE.MANAGEMENT.If_R_Change
ELSE RESOURCE.MANAGEMENT.GeneDep_Rate+RESOURCE.MANAGEMENT.If_No_R_Change
DOCUMENT: If there are no "Biosafety Industry Resources" then depletion "Factor" increases 0.05, if "BIR" is positive
within a range then "Factor" decreases (depending on the level: 0<BIR<1000 then the "Bio Effect Change" (0.5) is al-
tered by either a factor of 50%, 25%, 10%, or 0).
: f RESOURCE.MANAGEMENT.Out_GR_Dep = RESOURCE.MANAGEMENT.GeneDep_Rate
: c R&D.POLICY.Intl_Bio_Standard = 2.15
: c R&D.POLICY.PubDep_Thres = R&D.POLICY.Intl_Bio_Standard
: c R&D.POLICY.Public_Perception = RESOURCE.MANAGEMENT.Depletion_Rate-R&D.POLICY.PubDep_Thres
: c R&D.POLICY.PP_Effect =
IF R&D.POLICY.Public_Perception>0
THEN 0.01
ELSE 0
: f R&D.POLICY.In_BLev =
IF (R&D.POLICY.Biosafety_Level+R&D.POLICY.PP_Effect) > R&D.POLICY.Intl_Bio_Standard
THEN ((R&D.POLICY.Biosafety_Level+R&D.POLICY.PP_Effect)-1)
ELSE (R&D.POLICY.Biosafety_Level+R&D.POLICY.PP_Effect)
: f R&D.POLICY.Out_BLev = R&D.POLICY.Biosafety_Level
: c R&D.POLICY.Tax_Rater_Change = 0.01
: c R&D.POLICY.T2 =
IF RESOURCE.MANAGEMENT.Net_Res_Govt<10000
THEN (-1*R&D.POLICY.Tax_Rater_Change)
ELSE 0
: c R&D.POLICY.T1 =
IF RESOURCE.MANAGEMENT.Net_Res_Govt> 1000000
THEN (R&D.POLICY.Tax_Rater_Change)
ELSE R&D.POLICY.T2
: f R&D.POLICY.In_Tax_Change = R&D.POLICY.Tax_Rate+R&D.POLICY.T1

```

```

: f R&D.POLICY.Out.Tax.Change = R&D.POLICY.Tax.Rate
: c R&D.POLICY.R.Invest.Change = 0.001
: c R&D.POLICY.R&D2 =
IF R&D.POLICY.Tax.Rate < 0.35
THEN -1*R&D.POLICY.R.Invest.Change
ELSE 0
: c R&D.POLICY.R&D1 =
IF R&D.POLICY.Tax.Rate > 0.35
THEN R&D.POLICY.R.Invest.Change
ELSE R&D.POLICY.R&D2
: f R&D.POLICY.In_R&D.Rate = R&D.POLICY.R&D.Rate+R&D.POLICY.R&D1
: f R&D.POLICY.Out_R&D.Rate = R&D.POLICY.R&D.Rate
: c R&D.POLICY.Intl.HS.Rate = 0.02
: f R&D.POLICY.In.HSR = R&D.POLICY.Intl.HS.Rate
: f R&D.POLICY.Out.HSR = R&D.POLICY.Health.Safe.Rate
: c R&D.POLICY.Infra_Invest.Change = 0.001
: c R&D.POLICY.Infra2 =
IF R&D.POLICY.R&D.Rate < 0.6
THEN -1*R&D.POLICY.Infra_Invest.Change
ELSE 0
: c R&D.POLICY.Infra1 =
IF R&D.POLICY.R&D.Rate > 0.84
THEN R&D.POLICY.Infra_Invest.Change
ELSE R&D.POLICY.Infra2
: f R&D.POLICY.In.Infra.Rate = R&D.POLICY.Infra.Rate+R&D.POLICY.Infra1
: f R&D.POLICY.Out.Infra.Rate = R&D.POLICY.Infra.Rate
: c R&D.POLICY.Breadth = 0.5
: c RESOURCE.MANAGEMENT.Spread =
(RESOURCE.MANAGEMENT.GRDep%-RESOURCE.MANAGEMENT.Gene.Prospect)*100
: c R&D.POLICY.APP_Rate.Change = -0.01
: c R&D.POLICY.Effective_App.Rate =
IF RESOURCE.MANAGEMENT.Spread > 0.25
THEN R&D.POLICY.APP_Rate.Change
ELSE 0
: f R&D.POLICY.In.BFact = R&D.POLICY.Breadth+R&D.POLICY.Effective_App.Rate
: f R&D.POLICY.Out.BFact = R&D.POLICY.Breadth.Fact
: c R&D.POLICY.Length.Fact = R&D.POLICY.Length/25
DOCUMENT: One in this converter means that the length of a patent protection is 25 years without extension. Any
changes to the length will alter the level.
: f R&D.POLICY.In_IPR =
IF (R&D.POLICY.In.BFact*R&D.POLICY.Length.Fact) <1
THEN (R&D.POLICY.In.BFact*R&D.POLICY.Length.Fact)
ELSE 1
: f R&D.POLICY.Out_IPR = R&D.POLICY.IPR.Effect
: s R&D.POLICY.HS.Inspect.Level = 200000
: s INNOVATION.MANAGEMENT.Health_S.Fund = 10000000
: c R&D.POLICY.HS.Degree = 5000
: c R&D.POLICY.HS.Change1 =
IF NOT(INNOVATION.MANAGEMENT.Health_S.Fund<10000000)
THEN (R&D.POLICY.HS.Inspect.Level-R&D.POLICY.HS.Degree)
ELSE 0
: c R&D.POLICY.HS.Change =
IF INNOVATION.MANAGEMENT.Health_S.Fund<10000000
THEN (R&D.POLICY.HS.Inspect.Level+R&D.POLICY.HS.Degree)
ELSE R&D.POLICY.HS.Change1

```

```

: f R&D_POLICY.In_HSIL = R&D_POLICY.HS.Change
: f R&D_POLICY.Out_HSIL = R&D_POLICY.HS.Inspect.Level
: s INNOVATION_MANAGEMENT.Free_Access_A1 = 0
: f INNOVATION_MANAGEMENT.To_FreeA1 = CONVEYOR OUTFLOW
: f INNOVATION_MANAGEMENT.To_PubKnow = INNOVATION_MANAGEMENT.Free_Access_A1
: c INNOVATION_MANAGEMENT.Bio_Prob.Change = 1
: c INNOVATION_MANAGEMENT.Bio_Effect5 =
IF NOT(INNOVATION_MANAGEMENT.Bio_Ind_Res>1000000) AND INNOVATION_MANAGEMENT.Bio_Ind_Res
> 100000
THEN 0.05*INNOVATION_MANAGEMENT.Bio_Prob.Change
ELSE 0
: c INNOVATION_MANAGEMENT.Bio_Effect4 =
IF NOT(INNOVATION_MANAGEMENT.Bio_Ind_Res>2500000) AND INNOVATION_MANAGEMENT.Bio_Ind_Res
> 1000000
THEN 0.1*INNOVATION_MANAGEMENT.Bio_Prob.Change
ELSE INNOVATION_MANAGEMENT.Bio_Effect5
: c INNOVATION_MANAGEMENT.Bio_Effect3 =
IF NOT (INNOVATION_MANAGEMENT.Bio_Ind_Res>5000000) AND INNOVATION_MANAGEMENT.Bio_Ind_Res
> 2500000
THEN INNOVATION_MANAGEMENT.Bio_Prob.Change*0.25
ELSE INNOVATION_MANAGEMENT.Bio_Effect4
: c INNOVATION_MANAGEMENT.Bio_Effect2 =
IF NOT( INNOVATION_MANAGEMENT.Bio_Ind_Res>10000000
OR INNOVATION_MANAGEMENT.Bio_Ind_Res=0) AND INNOVATION_MANAGEMENT.Bio_Ind_Res>5000000
THEN INNOVATION_MANAGEMENT.Bio_Prob.Change*0.5
ELSE INNOVATION_MANAGEMENT.Bio_Effect3
: c INNOVATION_MANAGEMENT.Bio_Effect1 =
IF INNOVATION_MANAGEMENT.Bio_Ind_Res > 10000000
THEN INNOVATION_MANAGEMENT.Bio_Prob.Change
ELSE INNOVATION_MANAGEMENT.Bio_Effect2
: c INNOVATION_MANAGEMENT.Bio_Effect =
IF INNOVATION_MANAGEMENT.Bio_Ind_Res =0
THEN INNOVATION_MANAGEMENT.Bio_Prob.Change*INNOVATION_MANAGEMENT.Bio_Ind_Res
ELSE INNOVATION_MANAGEMENT.Bio_Effect1
: c INNOVATION_MANAGEMENT.If_Change =
IF INNOVATION_MANAGEMENT.Bio_Effect >0
THEN INNOVATION_MANAGEMENT.Bio_Effect
ELSE 0
: c INNOVATION_MANAGEMENT.If_No_Change = 0.5
: f INNOVATION_MANAGEMENT.In_Prob =
IF INNOVATION_MANAGEMENT.If_Change > 0
THEN (INNOVATION_MANAGEMENT.Bio_Prob+INNOVATION_MANAGEMENT.If_Change)
ELSE (INNOVATION_MANAGEMENT.Bio_Prob-INNOVATION_MANAGEMENT.If_No_Change)
: f INNOVATION_MANAGEMENT.Out_Prob = INNOVATION_MANAGEMENT.Bio_Prob
: c INNOVATION_MANAGEMENT.R_Infra_Dep = 0.025
: f INNOVATION_MANAGEMENT.In_R_Infra = RESOURCE_MANAGEMENT.BR_Infra_Res
DOCUMENT: Each infrastructure unit (or research center, i.e. university) is valued in 50,000 units.
Each researcher (Lr) requires
: f INNOVATION_MANAGEMENT.Out_R_Infra =
INNOVATION_MANAGEMENT.R_Infra*INNOVATION_MANAGEMENT.R_Infra_Dep
: c INNOVATION_MANAGEMENT.PK_Dep = EXP(-0.02*TIME)
: c INNOVATION_MANAGEMENT.eSDC = EXP(INNOVATION_MANAGEMENT.SpillDClust)
: c INNOVATION_MANAGEMENT.eSRC = EXP(INNOVATION_MANAGEMENT.SpillRClust)
: c INNOVATION_MANAGEMENT.No_Cluster = 0
: c INNOVATION_MANAGEMENT.V4 =

```

```

IF INNOVATION_MANAGEMENT.R.Clustering = 0 AND INNOVATION_MANAGEMENT.D.Clustering = 0
THEN INNOVATION_MANAGEMENT.No.Cluster
ELSE 0
: c INNOVATION_MANAGEMENT.V3 =
IF INNOVATION_MANAGEMENT.R.Clustering = 0 AND INNOVATION_MANAGEMENT.D.Clustering = 1
THEN INNOVATION_MANAGEMENT.eSDC
ELSE INNOVATION_MANAGEMENT.V4
: c INNOVATION_MANAGEMENT.V2 =
IF INNOVATION_MANAGEMENT.R.Clustering = 1 AND INNOVATION_MANAGEMENT.D.Clustering = 0
THEN INNOVATION_MANAGEMENT.eSRC
ELSE INNOVATION_MANAGEMENT.V3
: c INNOVATION_MANAGEMENT.V1 =
IF INNOVATION_MANAGEMENT.R.Clustering = 1 AND INNOVATION_MANAGEMENT.D.Clustering = 1
THEN (INNOVATION_MANAGEMENT.eSDC+INNOVATION_MANAGEMENT.eSRC)
ELSE INNOVATION_MANAGEMENT.V2
: c INNOVATION_MANAGEMENT.V0 =
IF INNOVATION_MANAGEMENT.V1 = 2
THEN 0
ELSE INNOVATION_MANAGEMENT.V1
: c INNOVATION_MANAGEMENT.Spillover_Effect =
IF INNOVATION_MANAGEMENT.V1 = 1
THEN 0
ELSE INNOVATION_MANAGEMENT.V0
: f INNOVATION_MANAGEMENT.In.PubKnowl =
(INNOVATION_MANAGEMENT.TTe-INNOVATION_MANAGEMENT.R2DTech.Transfer)+
EXP(INNOVATION_MANAGEMENT.To_PubKnow)+INNOVATION_MANAGEMENT.Spillover_Effect
DOCUMENT: Since "Patented A1 Rate" = LOGN(R2DTech Transfer and "Public Knowledge Rate" requires the non-
LOGN version of "PA1R," "R2DTech Transfer" is used instead in this equation.
: f INNOVATION_MANAGEMENT.Out.PubKnow =
INNOVATION_MANAGEMENT.Public_Know*INNOVATION_MANAGEMENT.PK_Dep
: f RESOURCE_MANAGEMENT.To_D.Infra =
(1-RESOURCE_MANAGEMENT.D.Income_Frac)*RESOURCE_MANAGEMENT.Out.Total_ResD
: f INNOVATION_MANAGEMENT.In.D.Infra =
RESOURCE_MANAGEMENT.To_D.Infra
: f INNOVATION_MANAGEMENT.Out.D.Infra =
INNOVATION_MANAGEMENT.D.Infra*INNOVATION_MANAGEMENT.R.Infra_Dep
: f INNOVATION_MANAGEMENT.Out.HS.Fund =
IF DEVELOPMENT.Successful_D > 0
THEN R&D_POLICY.HS.Inspect.Level
ELSE 0
: c INNOVATION_MANAGEMENT.HS.Prob.Change = 1
: c INNOVATION_MANAGEMENT.HS.Effect5 =
IF NOT(INNOVATION_MANAGEMENT.Health_S.Fund > 7000000) AND INNOVATION_MANAGEMENT.Health_S.Fund
> 6000000
THEN 0.05*INNOVATION_MANAGEMENT.HS.Prob.Change
ELSE 0
: c INNOVATION_MANAGEMENT.HS.Effect4 =
IF NOT(INNOVATION_MANAGEMENT.Health_S.Fund > 8000000) AND INNOVATION_MANAGEMENT.Health_S.Fund
> 7000000
THEN 0.25*INNOVATION_MANAGEMENT.HS.Prob.Change
ELSE INNOVATION_MANAGEMENT.HS.Effect5
: c INNOVATION_MANAGEMENT.HS.Effect3 =
IF NOT (INNOVATION_MANAGEMENT.Health_S.Fund > 9000000) AND INNOVATION_MANAGEMENT.Health_S.Fund
> 8000000
THEN INNOVATION_MANAGEMENT.HS.Prob.Change*0.5

```

```

ELSE INNOVATION_MANAGEMENT.HS_Effect4
: c INNOVATION_MANAGEMENT.HS_Effect2 =
IF NOT( INNOVATION_MANAGEMENT.Health_S.Fund>10000000
OR INNOVATION_MANAGEMENT.Health_S.Fund=0) AND INNOVATION_MANAGEMENT.Health_S.Fund>9000000
THEN INNOVATION_MANAGEMENT.HS_Prob_Change*0.75
ELSE INNOVATION_MANAGEMENT.HS_Effect3
: c INNOVATION_MANAGEMENT.HS_Effect1 =
IF INNOVATION_MANAGEMENT.Health_S.Fund >10000000
THEN INNOVATION_MANAGEMENT.HS_Prob_Change
ELSE INNOVATION_MANAGEMENT.HS_Effect2
: c INNOVATION_MANAGEMENT.HS_Effect =
IF INNOVATION_MANAGEMENT.Health_S.Fund =0
THEN INNOVATION_MANAGEMENT.HS_Prob_Change*INNOVATION_MANAGEMENT.Health_S.Fund
ELSE INNOVATION_MANAGEMENT.HS_Effect1
: c INNOVATION_MANAGEMENT.If_HS_Change =
IF INNOVATION_MANAGEMENT.HS_Effect >0
THEN INNOVATION_MANAGEMENT.HS_Effect
ELSE 0
: c INNOVATION_MANAGEMENT.If_HS_No_Change = 0.5
: f INNOVATION_MANAGEMENT.In_HS_Prob =
IF INNOVATION_MANAGEMENT.If_HS_Change > 0
THEN INNOVATION_MANAGEMENT.HS_Prob+INNOVATION_MANAGEMENT.If_HS_Change
ELSE INNOVATION_MANAGEMENT.HS_Prob-INNOVATION_MANAGEMENT.If_HS_No_Change
: f INNOVATION_MANAGEMENT.Out_HS_Prob = INNOVATION_MANAGEMENT.HS_Prob
: c RESOURCE_MANAGEMENT.Mobility_Cap = 1
: c RESOURCE_MANAGEMENT.RtoD_Rate = 0.85
DOCUMENT: This changed from Spain's 0.77 to Mexico's 0.85
: c RESOURCE_MANAGEMENT.Prop_RtoD =
IF RESOURCE_MANAGEMENT.Mobility_Cap = 1
THEN RESOURCE_MANAGEMENT.Out_RD%Mob
ELSE RESOURCE_MANAGEMENT.RtoD_Rate
: f RESOURCE_MANAGEMENT.In_R_Lab =
RESOURCE_MANAGEMENT.Biotech_Labor*RESOURCE_MANAGEMENT.Prop_RtoD
: f RESOURCE_MANAGEMENT.In_D_Lab =
RESOURCE_MANAGEMENT.Biotech_Labor*(1-RESOURCE_MANAGEMENT.Prop_RtoD)
: f INNOVATION_MANAGEMENT.In_Lic_R_Clt = INNOVATION_MANAGEMENT.In_LicR
: f INNOVATION_MANAGEMENT.In_Lic_D_Clt = INNOVATION_MANAGEMENT.In_LicD
: f DEVELOPMENT.Off_Market = CONVEYOR OUTFLOW
: f RESOURCE_MANAGEMENT.In_Total_ResD =
RESOURCE_MANAGEMENT.PreTax_Kd-(RESOURCE_MANAGEMENT.PreTax_Kd*R&D_POLICY.Tax_Rate)
: f RESOURCE_MANAGEMENT.In_Govt_D =
RESOURCE_MANAGEMENT.Out_Res_Govt*((1-R&D_POLICY.R&D_Rate)-R&D_POLICY.Infra_Rate)
DOCUMENT: The net rate of investment the government allocates for development activities in biotech is so small
(1-R&D rate)-Infra rate, because it is assumed in the model that the vast majority of development activities take place
within the private sector, therefore not requiring governmental subsidy.
: f RESOURCE_MANAGEMENT.To_R_Lab = CONVEYOR OUTFLOW
: f RESOURCE_MANAGEMENT.To_D_Lab = CONVEYOR OUTFLOW
: c RESOURCE_MANAGEMENT.Intl_VC_Switch = 1
: c RESOURCE_MANAGEMENT.VCI1 =
IF RESOURCE_MANAGEMENT.VC_Total < 10000000 AND RESOURCE_MANAGEMENT.VC1= 2
THEN RESOURCE_MANAGEMENT.Out_Intl_VC
ELSE 0
: c RESOURCE_MANAGEMENT.VCIR =
IF RESOURCE_MANAGEMENT.Intl_VC_Switch = 1
THEN RESOURCE_MANAGEMENT.VCI1

```

```

ELSE 0
: c RESOURCE_MANAGEMENT.VCI3 =
IF RESOURCE_MANAGEMENT.VC.Total<1000000 AND NOT(RESOURCE_MANAGEMENT.VC1 =2
OR RESOURCE_MANAGEMENT.VC1=3) AND RESOURCE_MANAGEMENT.VC1 =4
THEN 0.5*RESOURCE_MANAGEMENT.Out.Inlt.VC
ELSE 0
: c RESOURCE_MANAGEMENT.VCI_Splt =
IF RESOURCE_MANAGEMENT.Intl.VC.Switch = 1
THEN RESOURCE_MANAGEMENT.VCI3
ELSE 0
: c RESOURCE_MANAGEMENT.SpltVCR =
IF NOT(RESOURCE_MANAGEMENT.VC1=2) AND RESOURCE_MANAGEMENT.VC1=4
THEN (0.5*RESOURCE_MANAGEMENT.Out.VC+RESOURCE_MANAGEMENT.VCI_Splt)
ELSE 0
: f RESOURCE_MANAGEMENT.In.VCtoR =
IF RESOURCE_MANAGEMENT.VC1 = 2
THEN (RESOURCE_MANAGEMENT.Out.VC+RESOURCE_MANAGEMENT.VCI_R)
ELSE RESOURCE_MANAGEMENT.SpltVCR
: c RESOURCE_MANAGEMENT.VCI2 =
IF RESOURCE_MANAGEMENT.VC.Total < 1000000 AND RESOURCE_MANAGEMENT.VC1 = 3
THEN RESOURCE_MANAGEMENT.Out.Inlt.VC
ELSE 0
: c RESOURCE_MANAGEMENT.VCID =
IF RESOURCE_MANAGEMENT.Intl.VC.Switch = 1
THEN RESOURCE_MANAGEMENT.VCI2
ELSE 0
: c RESOURCE_MANAGEMENT.SpltVCD =
IF NOT(RESOURCE_MANAGEMENT.VC1=3) AND RESOURCE_MANAGEMENT.VC1=4
THEN (0.5*RESOURCE_MANAGEMENT.Out.VC+RESOURCE_MANAGEMENT.VCI_Splt)
ELSE 0
: f RESOURCE_MANAGEMENT.In.VCtoD =
IF RESOURCE_MANAGEMENT.VC1 = 3
THEN (RESOURCE_MANAGEMENT.Out.VC+RESOURCE_MANAGEMENT.VCID)
ELSE RESOURCE_MANAGEMENT.SpltVCD
: c INNOVATION_MANAGEMENT.Total.R&D.Infra =
INNOVATION_MANAGEMENT.D.Infra+INNOVATION_MANAGEMENT.R.Infra

```

RUNTIME EQUATIONS

```

: s INNOVATION_MANAGEMENT.Public_Know(t) =
INNOVATION_MANAGEMENT.Public_Know(t-dt)+
(INNOVATION_MANAGEMENT.In.PubKnowI - INNOVATION_MANAGEMENT.Out.PubKnow) * dt
: s INNOVATION_MANAGEMENT.Licensed_R(t) =
INNOVATION_MANAGEMENT.Licensed_R(t-dt) +
(INNOVATION_MANAGEMENT.In.LicR - INNOVATION_MANAGEMENT.Out.A1_R) * dt
: s DEVELOPMENT.NDi1(t) =
DEVELOPMENT.NDi1(t-dt) + (DEVELOPMENT.Successful_LD - DEVELOPMENT.Out.i1) * dt
: s RESEARCH.New_R_Knowledge_A1(t) =
RESEARCH.New_R_Knowledge_A1(t-dt) + (RESEARCH.Successful_R - RESEARCH.To_Tech_Transfer) * dt
: s R&D.POLICY.IPR_Effect(t) =
R&D.POLICY.IPR_Effect(t-dt) + (R&D.POLICY.In_IPR - R&D.POLICY.Out_IPR) * dt
: s INNOVATION_MANAGEMENT.R.Infra(t) =

```

$INNOVATION_MANAGEMENT.R.Infra(t-dt) +$

$(INNOVATION_MANAGEMENT.In.R.Infra - INNOVATION_MANAGEMENT.Out.R.Infra) * dt$

DOCUMENT: The volume of resources in terms of infrastructure in basic research reaches the 250M and each researcher requires a level of 10,000 per period to produce research. There are 126 research centers and 145 affiliated research units in Spain. It is assumed that each has an approximate budget of 2m and 1m, respectively, per period.

: s $RESOURCE_MANAGEMENT.Available.Lr(t) =$

$RESOURCE_MANAGEMENT.Available.Lr(t-dt) + (RESOURCE_MANAGEMENT.To.R.Lab) * dt$

: s $RESOURCE_MANAGEMENT.Govt.R(t) =$

$RESOURCE_MANAGEMENT.Govt.R(t-dt) +$

$(RESOURCE_MANAGEMENT.In.Govt.R - RESOURCE_MANAGEMENT.Out.Govt.R) * dt$

DOCUMENT: This is 80% of 507m which is the total public subvention to research (p.32 Genoma Espana) and adds both Central and Community resources.

: s $RESOURCE_MANAGEMENT.Net.Res.Govt(t) =$

$RESOURCE_MANAGEMENT.Net.Res.Govt(t-dt) +$

$(RESOURCE_MANAGEMENT.In.Res.Govt - RESOURCE_MANAGEMENT.Out.Res.Govt) * dt$

: s $INNOVATION_MANAGEMENT.Licensed.D(t) =$

$INNOVATION_MANAGEMENT.Licensed.D(t-dt) +$

$(INNOVATION_MANAGEMENT.In.LicD - INNOVATION_MANAGEMENT.Out.A1.D) * dt$

: s $INNOVATION_MANAGEMENT.D.Infra(t) =$

$INNOVATION_MANAGEMENT.D.Infra(t-dt) +$

$(INNOVATION_MANAGEMENT.In.D.Infra - INNOVATION_MANAGEMENT.Out.D.Infra) * dt$

DOCUMENT: There are approximately 275 biotech industries in Spain (with 107 only in Cataluna and Madrid). These have at least 15 individuals working at them in development activities. The total resources these had in 2008 were slightly above 180M.

: s $RESOURCE_MANAGEMENT.Available.Ld(t) =$

$RESOURCE_MANAGEMENT.Available.Ld(t-dt) + (RESOURCE_MANAGEMENT.To.D.Lab) * dt$

DOCUMENT: I assume that the labor hand does not reduce itself due to the short period of time this analysis extends.

: s $RESOURCE_MANAGEMENT.Govt.D(t) =$

$RESOURCE_MANAGEMENT.Govt.D(t-dt) +$

$(RESOURCE_MANAGEMENT.In.Govt.D - RESOURCE_MANAGEMENT.Out.Govt.D) * dt$

DOCUMENT: This comes from p.32 Genoma Espana and represents approximately 14% of the total public subvention to R&D, as suggested. It includes both the local and community resources.

: s $RESOURCE_MANAGEMENT.VCtoD(t) =$

$RESOURCE_MANAGEMENT.VCtoD(t-dt) +$

$(RESOURCE_MANAGEMENT.In.VCtoD - RESOURCE_MANAGEMENT.Out.VCtoD) * dt$

: s $RESOURCE_MANAGEMENT.NetFin.ResR(t) =$

$RESOURCE_MANAGEMENT.NetFin.ResR(t-dt) +$

$(RESOURCE_MANAGEMENT.In.ResR - RESOURCE_MANAGEMENT.Out.NetFinR) * dt$

DOCUMENT: This comes from the total sales reported by public biotech entities (747m). Source: p.69 Genoma Espana, 2009.

: s $RESOURCE_MANAGEMENT.NetFin.ResD(t) =$

$RESOURCE_MANAGEMENT.NetFin.ResD(t-dt) +$

$(RESOURCE_MANAGEMENT.In.Net.Fin.D - RESOURCE_MANAGEMENT.Out.Net.Fin.D) * dt$

DOCUMENT: This comes from the total sales presented by the biotech industry in Spain for the year 2008 (684M)

Source: p.69 Genoma Espana, 2009.

: s RESOURCE_MANAGEMENT.Total_ResD(t) =
RESOURCE_MANAGEMENT.Total_ResD(t-dt) +
(RESOURCE_MANAGEMENT.In_Total_ResD - RESOURCE_MANAGEMENT.Out_Total_ResD) * dt

: s RESOURCE_MANAGEMENT.Nat_Res_D(t) =
RESOURCE_MANAGEMENT.Nat_Res_D(t-dt) +
(RESOURCE_MANAGEMENT.NatRes_Reg - RESOURCE_MANAGEMENT.NatRes_Dep) * dt

DOCUMENT: Natural Resources are decreasing at a rate that will deplete these to half of its current stock in 100 years.

: s RESOURCE_MANAGEMENT.Depletion_Rate(t) =
RESOURCE_MANAGEMENT.Depletion_Rate(t-dt) +
(RESOURCE_MANAGEMENT.In_DR - RESOURCE_MANAGEMENT.Out_DR) * dt

DOCUMENT: Natural Resources are being depleted by many factors exogenous to biotech R&D. These resources are being depleted at around 0.3% yearly and it is estimated that 1/3 of these will be gone in a century. However, these biotech activities account for around 20% of the depleted resources yearly. Yet, through the application of biosafety measures, the depletion rate accounted to R&D can be reduced overtime.

: s DEVELOPMENT.Development_Potential(t) =
DEVELOPMENT.Development_Potential(t-dt) + (DEVELOPMENT.Input_D - DEVELOPMENT.Output_D) * dt

: s INNOVATION_MANAGEMENT.Bio_Prob(t) =
INNOVATION_MANAGEMENT.Bio_Prob(t-dt) +
(INNOVATION_MANAGEMENT.In_Prob - INNOVATION_MANAGEMENT.Out_Prob) * dt

DOCUMENT: This is a Montecarlo probability that increases as the funding for biosafety increases. The larger the probability, the more probable a biotech product will reach the market.

: s INNOVATION_MANAGEMENT.HS_Prob(t) =
INNOVATION_MANAGEMENT.HS_Prob(t-dt) +
(INNOVATION_MANAGEMENT.In_HS_Prob - INNOVATION_MANAGEMENT.Out_HS_Prob) * dt

DOCUMENT: This is a Montecarlo probability that increases as the funding for biosafety increases. The larger the probability, the more probable a biotech product will reach the market.

: s R&D.POLICY.Biosafety_Level(t) =
R&D.POLICY.Biosafety_Level(t-dt) + (R&D.POLICY.In_BLEv - R&D.POLICY.Out_BLEv) * dt

: s R&D.POLICY.Health_Safe_Rate(t) =
R&D.POLICY.Health_Safe_Rate(t-dt) + (R&D.POLICY.In_HSR - R&D.POLICY.Out_HSR) * dt

: s R&D.POLICY.Tax_Rate(t) =
R&D.POLICY.Tax_Rate(t-dt) + (R&D.POLICY.In_Tax_Change - R&D.POLICY.Out_Tax_Change) * dt

: s RESOURCE_MANAGEMENT.TechT_RtoD(t) =
RESOURCE_MANAGEMENT.TechT_RtoD(t-dt) +
(RESOURCE_MANAGEMENT.In_TT_from_D - RESOURCE_MANAGEMENT.Out_TT_From_D) * dt

: s RESOURCE_MANAGEMENT.R.Save(t) =
RESOURCE_MANAGEMENT.R.Save(t-dt) +
(RESOURCE_MANAGEMENT.In_R.Save - RESOURCE_MANAGEMENT.Out_R.Save) * dt

: s RESOURCE_MANAGEMENT.R.Income(t) =
RESOURCE_MANAGEMENT.R.Income(t-dt) +
(RESOURCE_MANAGEMENT.In_R.Inc - RESOURCE_MANAGEMENT.Out_R.Inc) * dt

: s RESOURCE_MANAGEMENT.TechT_RtoR(t) =
RESOURCE_MANAGEMENT.TechT_RtoR(t-dt) +

$(\text{RESOURCE_MANAGEMENT.In.TT_from_R} - \text{RESOURCE_MANAGEMENT.Out.TT_From_R}) * dt$

: s $\text{RESOURCE_MANAGEMENT.Risk_Free_Comp}(t) =$
 $\text{RESOURCE_MANAGEMENT.Risk_Free_Comp}(t-dt) +$
 $(\text{RESOURCE_MANAGEMENT.To_Compound}) * dt$

DOCUMENT: This means this funds are invested in government bonds, thus, these resources are going back to the government.

: s $\text{R\&D.POLICY.R\&D_Rate}(t) =$
 $\text{R\&D.POLICY.R\&D_Rate}(t-dt) +$
 $(\text{R\&D.POLICY.In_R\&D_Rate} - \text{R\&D.POLICY.Out_R\&D_Rate}) * dt$

DOCUMENT: This rate comes from p.32 in the 2009 Genoma Espana report.

: s $\text{RESOURCE_MANAGEMENT.VCtoR}(t) =$
 $\text{RESOURCE_MANAGEMENT.VCtoR}(t-dt) +$
 $(\text{RESOURCE_MANAGEMENT.In.VCtoR} - \text{RESOURCE_MANAGEMENT.Out.VCtoR}) * dt$

: s $\text{RESOURCE_MANAGEMENT.Gene_Res}(t) =$
 $\text{RESOURCE_MANAGEMENT.Gene_Res}(t-dt) +$
 $(\text{RESOURCE_MANAGEMENT.In_Gene_Res} - \text{RESOURCE_MANAGEMENT.Out_Gene_Res}) * dt$

: s $\text{RESOURCE_MANAGEMENT.GeneDep_Rate}(t) =$
 $\text{RESOURCE_MANAGEMENT.GeneDep_Rate}(t-dt) +$
 $(\text{RESOURCE_MANAGEMENT.In_GR_Dep} - \text{RESOURCE_MANAGEMENT.Out_GR_Dep}) * dt$

DOCUMENT: Genetic Resources are being depleted by biotech R&D. In the model these resources are being prospected at around 0.3% yearly and it is estimated that 1/3 of these will be protected by IPRs in a century. Biotech activities account for the entire genetic resource erosion. Yet, through less secluding IPR measures, access to the information generated by these resources can be increased overtime.

: s $\text{RESEARCH.Research_Potential}(t) =$
 $\text{RESEARCH.Research_Potential}(t-dt) + (\text{RESEARCH.Input_R} - \text{RESEARCH.Output_R}) * dt$

: s $\text{RESOURCE_MANAGEMENT.Biotech_Labor}(t) =$
 $\text{RESOURCE_MANAGEMENT.Biotech_Labor}(t-dt) +$
 $(\text{RESOURCE_MANAGEMENT.In_BioLab} - \text{RESOURCE_MANAGEMENT.Out_BioLab}) * dt$

DOCUMENT: 100

: s $\text{INNOVATION_MANAGEMENT.Bio_Ind_Res}(t) =$
 $\text{INNOVATION_MANAGEMENT.Bio_Ind_Res}(t-dt) +$
 $(\text{INNOVATION_MANAGEMENT.In_Bio_Ind} - \text{INNOVATION_MANAGEMENT.Bio_Ind_to_Govt}) * dt$

DOCUMENT: Biosafety pertains to preserving the balance of natural resources. In the model it focuses on preventing over depleting natural resources. The access to genetic resources, as related to the access to and management of information derived from genetic information, is considered within its own subsystem. In this sense, development deals exclusively with biosafety while research deals exclusively with the access to genetic resources.

It is associated only to development because it deals with the protection of natural resources from the effects of developed technologies, like LGMOs freed to the environment for experimental, trail, or commercial reasons. Research, on the other hand, deals with extracting basic information from a particular natural resource type in the form of genes or genetic resources.

: s $\text{RESOURCE_MANAGEMENT.BR_Infra_Res}(t) =$
 $\text{RESOURCE_MANAGEMENT.BR_Infra_Res}(t-dt) +$
 $(\text{RESOURCE_MANAGEMENT.In_BR_Infra} - \text{RESOURCE_MANAGEMENT.Out_BR_Infra}) * dt$

DOCUMENT: Public Infrastructure is endowed with a 100,000 monetary units at t0. It is assumed that there is an initial

infrastructure of 10 research centers each worth 10,000 monetary units. Public infrastructure, however, depreciates at a linear rate of 0.025 per period.

$$\begin{aligned} &: s \text{ RESOURCE_MANAGEMENT.Govt.Infra}(t) = \\ &\text{RESOURCE_MANAGEMENT.Govt.Infra}(t-dt) + \\ &(\text{RESOURCE_MANAGEMENT.In.Govt.Infra} - \text{RESOURCE_MANAGEMENT.Out.Govt.Infra}) * dt \end{aligned}$$

DOCUMENT: See the documents in the other two funds.

$$\begin{aligned} &: s \text{ R\&D.POLICY.Infra.Rate}(t) = \\ &\text{R\&D.POLICY.Infra.Rate}(t-dt) + (\text{R\&D.POLICY.In.Infra.Rate} - \text{R\&D.POLICY.Out.Infra.Rate}) * dt \end{aligned}$$

DOCUMENT: This rate comes from an approximation from p. 32 of the Genoma Espana 2009 report.

$$\begin{aligned} &: s \text{ RESOURCE_MANAGEMENT.D.Income}(t) = \\ &\text{RESOURCE_MANAGEMENT.D.Income}(t-dt) + \\ &(\text{RESOURCE_MANAGEMENT.In.D.Inc} - \text{RESOURCE_MANAGEMENT.Out.D.Inc}) * dt \end{aligned}$$

$$\begin{aligned} &: s \text{ RESOURCE_MANAGEMENT.D.Reinvest}(t) = \\ &\text{RESOURCE_MANAGEMENT.D.Reinvest}(t-dt) + \\ &(\text{RESOURCE_MANAGEMENT.In.D.Reinv} - \text{RESOURCE_MANAGEMENT.Out.D.Reinv}) * dt \end{aligned}$$

$$\begin{aligned} &: s \text{ RESOURCE_MANAGEMENT.VCRD.Bal}(t) = \\ &\text{RESOURCE_MANAGEMENT.VCRD.Bal}(t-dt) + \\ &(\text{RESOURCE_MANAGEMENT.In.VCRD.Bal} - \text{RESOURCE_MANAGEMENT.Out.VCRD.Bal}) * dt \end{aligned}$$

$$\begin{aligned} &: s \text{ RESOURCE_MANAGEMENT.VCR.Fund}(t) = \\ &\text{RESOURCE_MANAGEMENT.VCR.Fund}(t-dt) + \\ &(\text{RESOURCE_MANAGEMENT.In.VCR.Fund} - \text{RESOURCE_MANAGEMENT.Out.VCR.Fund}) * dt \end{aligned}$$

DOCUMENT: This fund is composed by the surplus generated when one exists after paying investors the amount these allocated for VC. It can also be negative when either R or D are not successful.

$$\begin{aligned} &: s \text{ RESOURCE_MANAGEMENT.VCtoR.Debt}(t) = \\ &\text{RESOURCE_MANAGEMENT.VCtoR.Debt}(t-dt) + \\ &(\text{RESOURCE_MANAGEMENT.In.VCR.Debt} - \text{RESOURCE_MANAGEMENT.Out.VCR.Debt}) * dt \end{aligned}$$

DOCUMENT: There is the need to coordinate the payment of this VC debt with the funds set to do so.

$$\begin{aligned} &: s \text{ RESOURCE_MANAGEMENT.VCRF.Bal}(t) = \\ &\text{RESOURCE_MANAGEMENT.VCRF.Bal}(t-dt) + \\ &(\text{RESOURCE_MANAGEMENT.In.VCRF.Bal} - \text{RESOURCE_MANAGEMENT.Out.VCRF.Bal}) * dt \end{aligned}$$

$$\begin{aligned} &: s \text{ RESOURCE_MANAGEMENT.D.Spend}(t) = \\ &\text{RESOURCE_MANAGEMENT.D.Spend}(t-dt) + \\ &(\text{RESOURCE_MANAGEMENT.In.D.Spend} - \text{RESOURCE_MANAGEMENT.Out.D.Spend}) * dt \end{aligned}$$

DOCUMENT: This is connected to the "To Market" level in order to buy out all products at the price level. Once there are no more "X.Spending," resources the income ends. This will set the price level and the success of the product in the market.

$$\begin{aligned} &: s \text{ RESOURCE_MANAGEMENT.D.Save}(t) = \\ &\text{RESOURCE_MANAGEMENT.D.Save}(t-dt) + \\ &(\text{RESOURCE_MANAGEMENT.In.D.Save} - \text{RESOURCE_MANAGEMENT.Out.D.Save}) * dt \end{aligned}$$

$$\begin{aligned} &: s \text{ RESOURCE_MANAGEMENT.R.Spend}(t) = \\ &\text{RESOURCE_MANAGEMENT.R.Spend}(t-dt) + \\ &(\text{RESOURCE_MANAGEMENT.In.R.Spend} - \text{RESOURCE_MANAGEMENT.Out.R.Spend}) * dt \end{aligned}$$

$$\begin{aligned} &: s \text{ RESOURCE_MANAGEMENT.All.Spend}(t) = \\ &\text{RESOURCE_MANAGEMENT.All.Spend}(t-dt) + \end{aligned}$$

$$\begin{aligned}
& (\text{RESOURCE_MANAGEMENT.In.Spend} - \text{RESOURCE_MANAGEMENT.Out.Spend}) * dt \\
: s \text{ RESOURCE_MANAGEMENT.All.Save}(t) = \\
& \text{RESOURCE_MANAGEMENT.All.Save}(t-dt) + \\
& (\text{RESOURCE_MANAGEMENT.In.Save} - \text{RESOURCE_MANAGEMENT.To.Invest}) * dt \\
: s \text{ RESOURCE_MANAGEMENT.RtoD.}\% \text{Mob}(t) = \\
& \text{RESOURCE_MANAGEMENT.RtoD.}\% \text{Mob}(t-dt) + \\
& (\text{RESOURCE_MANAGEMENT.In.RD}\% \text{Mob} - \text{RESOURCE_MANAGEMENT.Out.RD}\% \text{Mob}) * dt \\
: s \text{ RESOURCE_MANAGEMENT.Risk.Free.Inv}(t) = \\
& \text{RESOURCE_MANAGEMENT.Risk.Free.Inv}(t-dt) + \\
& (\text{RESOURCE_MANAGEMENT.To.Risk.Free} - \text{RESOURCE_MANAGEMENT.To.Compound}) * dt \\
: s \text{ RESOURCE_MANAGEMENT.VC.Total}(t) = \\
& \text{RESOURCE_MANAGEMENT.VC.Total}(t-dt) + \\
& (\text{RESOURCE_MANAGEMENT.To.VC} - \text{RESOURCE_MANAGEMENT.Out.VC}) * dt
\end{aligned}$$

DOCUMENT: Venture Capital is a fraction of all savings from both research and development activities. This fraction changes over time depending on its performance. It becomes invested in either research or development depending on the performance of capital spending in either sector (when VC1 = 2, it goes to R; when VC1 = 3, it goes to D; when VC1 = 4, it is spread evenly between the two; when VC1=1, it remains stocked); to decide this, capital investment (Kr or Kd) is compared to the "Net Financial Resources" of each sector. Whenever the NFR(r,d) of either sector is larger than the capital investment K (r,d) at any time, investors decide to invest in the sector. In the case when capital investment of either sector is less than its NFR venture capital is stocked until either sector displays larger NFR than K. The model, however, does not allow for both sectors to perform successfully simultaneously, meaning that $\text{NFR} > \text{Kr}$ and $\text{NFR} > \text{Kd}$ can not simultaneously exist. Original level 120m.

$$\begin{aligned}
: s \text{ RESOURCE_MANAGEMENT.VCtoD.Debt}(t) = \\
& \text{RESOURCE_MANAGEMENT.VCtoD.Debt}(t-dt) + \\
& (\text{RESOURCE_MANAGEMENT.In.VCD.Debt} - \text{RESOURCE_MANAGEMENT.Out.VCD.Debt}) * dt \\
: s \text{ RESOURCE_MANAGEMENT.VCD.Fund}(t) = \\
& \text{RESOURCE_MANAGEMENT.VCD.Fund}(t-dt) + \\
& (\text{RESOURCE_MANAGEMENT.In.VCD.Fund} - \text{RESOURCE_MANAGEMENT.Out.VCD.Fund}) * dt \\
: s \text{ RESOURCE_MANAGEMENT.VCDD.Bal}(t) = \\
& \text{RESOURCE_MANAGEMENT.VCDD.Bal}(t-dt) + \\
& (\text{RESOURCE_MANAGEMENT.In.VCDD.Bal} - \text{RESOURCE_MANAGEMENT.Out.VCDD.Bal}) * dt \\
: s \text{ RESOURCE_MANAGEMENT.VCDF.Bal}(t) = \\
& \text{RESOURCE_MANAGEMENT.VCDF.Bal}(t-dt) + \\
& (\text{RESOURCE_MANAGEMENT.In.VCDF.Bal} - \text{RESOURCE_MANAGEMENT.Out.VCDF.Bal}) * dt \\
: s \text{ RESOURCE_MANAGEMENT.Intl.VC.Fund}(t) = \\
& \text{RESOURCE_MANAGEMENT.Intl.VC.Fund}(t-dt) + \\
& (\text{RESOURCE_MANAGEMENT.In.Intl.VC} - \text{RESOURCE_MANAGEMENT.Out.Intl.VC}) * dt \\
: s \text{ R\&D.POLICY.Breadth.Fact}(t) = \\
& \text{R\&D.POLICY.Breadth.Fact}(t-dt) + (\text{R\&D.POLICY.In.BFact} - \text{R\&D.POLICY.Out.BFact}) * dt \\
: s \text{ R\&D.POLICY.HS.Inspect.Level}(t) = \\
& \text{R\&D.POLICY.HS.Inspect.Level}(t-dt) + \\
& (\text{R\&D.POLICY.In.HSIL} - \text{R\&D.POLICY.Out.HSIL}) * dt \\
: s \text{ INNOVATION_MANAGEMENT.Health.S.Fund}(t) = \\
& \text{INNOVATION_MANAGEMENT.Health.S.Fund}(t-dt) +
\end{aligned}$$

(INNOVATION_MANAGEMENT.In_HS.Fund - INNOVATION_MANAGEMENT.Out_HS.Fund) * dt
 : s INNOVATION_MANAGEMENT.Free_Access_A1(t) =
 INNOVATION_MANAGEMENT.Free_Access_A1(t-dt) +
 (INNOVATION_MANAGEMENT.To_FreeA1 - INNOVATION_MANAGEMENT.To_PubKnow) * dt
 : l DEVELOPMENT.In_Market(t) =
 DEVELOPMENT.In_Market(t-dt) +
 (DEVELOPMENT.To_Market - DEVELOPMENT.Off_Market) * dt
 : l RESOURCE_MANAGEMENT.R.Labor(t) =
 RESOURCE_MANAGEMENT.R.Labor(t-dt) +
 (RESOURCE_MANAGEMENT.In_R.Lab - RESOURCE_MANAGEMENT.To_R.Lab) * dt
 : l RESOURCE_MANAGEMENT.D.Labor(t) =
 RESOURCE_MANAGEMENT.D.Labor(t-dt) +
 (RESOURCE_MANAGEMENT.In_D.Lab - RESOURCE_MANAGEMENT.To_D.Lab) * dt
 : l INNOVATION_MANAGEMENT.Patent_A1(t) =
 INNOVATION_MANAGEMENT.Patent_A1(t-dt) +
 (INNOVATION_MANAGEMENT.In_Patent_A1 - INNOVATION_MANAGEMENT.To_FreeA1) * dt
 DOCUMENT: It is assumed that there is an initial endowment of 65 units within the patent pipeline before t0.
 : l INNOVATION_MANAGEMENT.LicR.Clust(t) =
 INNOVATION_MANAGEMENT.LicR.Clust(t-dt) +
 (INNOVATION_MANAGEMENT.In.Lic_R.Clt -
 INNOVATION_MANAGEMENT.Out.LicR.Clt - INNOVATION_MANAGEMENT.SpillRClust) * dt
 : l INNOVATION_MANAGEMENT.LicD.Clust(t) =
 INNOVATION_MANAGEMENT.LicD.Clust(t-dt) +
 (INNOVATION_MANAGEMENT.In.Lic_D.Clt -
 INNOVATION_MANAGEMENT.Out.Lic_D.Clt - INNOVATION_MANAGEMENT.SpillDClust) * dt
 : f INNOVATION_MANAGEMENT.SpillRClust = LEAKAGE OUTFLOW
 : f INNOVATION_MANAGEMENT.Out.LicR.Clt = CONVEYOR OUTFLOW
 : f RESEARCH.To_Tech.Transfer = RESEARCH.New_R.Knowledge_A1
 : c INNOVATION_MANAGEMENT.Match_Type_1 =
 IF DEVELOPMENT.NDi1 < 1 AND RESEARCH.To_Tech.Transfer > 0
 THEN 1
 ELSE 0
 : c INNOVATION_MANAGEMENT.Match_Type_2 =
 IF INNOVATION_MANAGEMENT.Match_Type_1 = 1
 THEN 0
 ELSE 1
 : c INNOVATION_MANAGEMENT.TTe = EXP(RESEARCH.To_Tech.Transfer)
 : c INNOVATION_MANAGEMENT.R2DTech.Transfer = INNOVATION_MANAGEMENT.TTe * R&D_POLICY.IPR_Effect
 : f INNOVATION_MANAGEMENT.In_Patent_A1 = LOGN(INNOVATION_MANAGEMENT.R2DTech.Transfer)
 : c INNOVATION_MANAGEMENT.Leftover_IP =
 IF INNOVATION_MANAGEMENT.Match_Type_2 = 1
 THEN INNOVATION_MANAGEMENT.In_Patent_A1
 ELSE INNOVATION_MANAGEMENT.IPRs_Transfer_%
 DOCUMENT: This suggest a "Clustering Effect" if returned to A1 in addition to "Public Knowledge." Its degree can

also be tuned depending on the clustering degree (If 1 then the full “Leftover IP” loops back to A1. Lower levels will refer to less percentage of flow, and so on. In the case that there is no Match type 2 then 15% of Patents goes to Research (assuming that if there is no real demand only about 30% of patents are licensed between R&D.

: f INNOVATION_MANAGEMENT.In.LicR = INNOVATION_MANAGEMENT.Leftover_IP

DOCUMENT: Since the financial resources to pay for the IPRs licenses are produced by “Research” and “Research” is getting these resources as payment, these are balanced out (out=In=0).

: f INNOVATION_MANAGEMENT.Out_A1_R = INNOVATION_MANAGEMENT.Licensed_R

: c INNOVATION_MANAGEMENT.A1_R =

IF INNOVATION_MANAGEMENT.R.Clustering =1

THEN INNOVATION_MANAGEMENT.Out.LicRCl

ELSE INNOVATION_MANAGEMENT.Out_A1_R

: c RESOURCE_MANAGEMENT.eA1R = EXP(INNOVATION_MANAGEMENT.A1_R)

: c RESOURCE_MANAGEMENT.TeA1R =

IF RESOURCE_MANAGEMENT.eA1R = 1

THEN RESOURCE_MANAGEMENT.eA1R =0

ELSE RESOURCE_MANAGEMENT.eA1R

: c INNOVATION_MANAGEMENT.R.Infra.L.Capacity =

INNOVATION_MANAGEMENT.R.Infra/INNOVATION_MANAGEMENT.Infra.Units.per.Lr

DOCUMENT: Each Lr requires 1000 R Infr L units to allow for Lr to turn into Human Capital (HC) by multiplying each matching 1 unit of Lr / 100 units of R Infra to A1 or A2 in the Research and Development modules.

: c RESOURCE_MANAGEMENT.ELr1 =

IF INNOVATION_MANAGEMENT.R.Infra.L.Capacity < RESOURCE_MANAGEMENT.Available.Lr

THEN INNOVATION_MANAGEMENT.R.Infra.L.Capacity

ELSE 0

: c RESOURCE_MANAGEMENT.Effective.Lr =

IF INNOVATION_MANAGEMENT.R.Infra.L.Capacity >= RESOURCE_MANAGEMENT.Available.Lr

THEN RESOURCE_MANAGEMENT.Available.Lr

ELSE RESOURCE_MANAGEMENT.ELr1

: c RESEARCH.HCr =

1+(INNOVATION_MANAGEMENT.Public.Know+

RESOURCE_MANAGEMENT.TeA1R)*RESOURCE_MANAGEMENT.Effective.Lr

DOCUMENT: Labor and information are multiplied to determine the human capital levels which can be measured in information units (each individual has all knowledge and it does not get depleted due to the public good character of information). The delay is introduced because it takes around five years for scientific personnel to become “knowledgeable in the art” and, thus, be considered “human capital.”

: f INNOVATION_MANAGEMENT.SpillDClust = LEAKAGE OUTFLOW

DOCUMENT: The spillover fraction is 0.4

: f INNOVATION_MANAGEMENT.Out.Lic.D.Cl = CONVEYOR OUTFLOW

: f INNOVATION_MANAGEMENT.In.LicD =

IF INNOVATION_MANAGEMENT.Match.Type.1 = 1

THEN INNOVATION_MANAGEMENT.In.Patent.A1

ELSE (INNOVATION_MANAGEMENT.IPRs.Transfer.>%*INNOVATION_MANAGEMENT.In.Patent.A1)

DOCUMENT: This logic suggests that the demand for research patents is full (highly, complete stock is demanded) when development’s technological stock is dry (equal to zero). Otherwise the average of licensed patents is just a frac-

tion (if “Match Making” mechanism exists) or zero (if no “Match Making” mechanism exists) of the total of patented A1.

: f INNOVATION_MANAGEMENT.Out_A1_D = INNOVATION_MANAGEMENT.Licensed_D

: c INNOVATION_MANAGEMENT.A1_D =

IF INNOVATION_MANAGEMENT.D.Clustering = 1

THEN INNOVATION_MANAGEMENT.Out.Lic.D.Clt

ELSE INNOVATION_MANAGEMENT.Out_A1_D

: c RESOURCE_MANAGEMENT.eA1D = EXP(INNOVATION_MANAGEMENT.A1_D)

: c RESOURCE_MANAGEMENT.TeA1D =

IF RESOURCE_MANAGEMENT.eA1D=1

THEN RESOURCE_MANAGEMENT.eA1D=0

ELSE RESOURCE_MANAGEMENT.eA1D

DOCUMENT: It is Total because the zeros where eliminated

: c INNOVATION_MANAGEMENT.D.Infra.L.Capacity =

INNOVATION_MANAGEMENT.D.Infra/INNOVATION_MANAGEMENT.Infra.Units_Per_Ld

: c RESOURCE_MANAGEMENT.ELd1 =

IF INNOVATION_MANAGEMENT.D.Infra.L.Capacity < RESOURCE_MANAGEMENT.Available_Ld

THEN INNOVATION_MANAGEMENT.D.Infra.L.Capacity

ELSE 0

: c RESOURCE_MANAGEMENT.Effective_Ld =

IF INNOVATION_MANAGEMENT.D.Infra.L.Capacity >= RESOURCE_MANAGEMENT.Available_Ld

THEN RESOURCE_MANAGEMENT.Available_Ld

ELSE RESOURCE_MANAGEMENT.ELd1

: c DEVELOPMENT.HCd =

1+(INNOVATION_MANAGEMENT.Public_Know+RESOURCE_MANAGEMENT.TeA1D)

*RESOURCE_MANAGEMENT.Effective_Ld

DOCUMENT: There is a need to include a +1 to this equation in order to be able to run the scenario where there is labor trade-off. Otherwise, since at points there is no change on human capital due to this variability, there is a division by zero when running the model using Euler’s method.

: f RESOURCE_MANAGEMENT.Out.Govt_D = RESOURCE_MANAGEMENT.Govt_D

: f RESOURCE_MANAGEMENT.Out.VCtoD = RESOURCE_MANAGEMENT.VCtoD

: f RESOURCE_MANAGEMENT.Out.Total_ResD = RESOURCE_MANAGEMENT.Total_ResD

: f RESOURCE_MANAGEMENT.In.Net_Fin_D =

(RESOURCE_MANAGEMENT.D.Income_Frac*RESOURCE_MANAGEMENT.Out.Total_ResD)

: f RESOURCE_MANAGEMENT.Out.Net_Fin_D = RESOURCE_MANAGEMENT.NetFin_ResD

: f RESOURCE_MANAGEMENT.In_D_Reinv =

RESOURCE_MANAGEMENT.Out.Net_Fin_D*RESOURCE_MANAGEMENT.D2D_Reinv

: c DEVELOPMENT.Kd =

1+RESOURCE_MANAGEMENT.Out.Govt_D+

RESOURCE_MANAGEMENT.Out.VCtoD+RESOURCE_MANAGEMENT.In_D_Reinv

: c RESOURCE_MANAGEMENT.NRDep% = RESOURCE_MANAGEMENT.Depletion_Rate/100

: f RESOURCE_MANAGEMENT.NatRes_Reg =

RESOURCE_MANAGEMENT.Nat_Res_D*RESOURCE_MANAGEMENT.Reg_Rate

: f RESOURCE_MANAGEMENT.NatRes_Dep =

```

RESOURCE_MANAGEMENT.Nat_Res_D*RESOURCE_MANAGEMENT.NRDep%
: f DEVELOPMENT.Input_D =
LOGN(DEVELOPMENT.HCd+DEVELOPMENT.Kd+
RESOURCE_MANAGEMENT.NatRes_Dep)
: c DEVELOPMENT.HCt0 = DELAY(DEVELOPMENT.HCd,1)
: c DEVELOPMENT.ProbHC =
1+(DEVELOPMENT.Degree_HC+
(DEVELOPMENT.Degree_HC*((DEVELOPMENT.HCd/DEVELOPMENT.HCt0)-1)))
: c DEVELOPMENT.ProbHC_Range =
IF DEVELOPMENT.ProbHC>100
THEN 100
ELSE DEVELOPMENT.ProbHC
: c DEVELOPMENT.MTCHC = MONTECARLO(DEVELOPMENT.ProbHC_Range)
: c DEVELOPMENT.Kt0 = DELAY(DEVELOPMENT.Kd,1)
: c DEVELOPMENT.ProbK =
DEVELOPMENT.Degree_K+(DEVELOPMENT.Degree_K*((DEVELOPMENT.Kd/DEVELOPMENT.Kt0)-1))
: c DEVELOPMENT.ProbK_Range =
IF DEVELOPMENT.ProbK>100
THEN 100
ELSE DEVELOPMENT.ProbK
: c DEVELOPMENT.MTCK = MONTECARLO(DEVELOPMENT.ProbK_Range)
: c DEVELOPMENT.SUMAt1 = DEVELOPMENT.MTCHC+DEVELOPMENT.MTCK
: c DEVELOPMENT.SUMAt0 = DELAY(DEVELOPMENT.SUMAt1,1)
: c DEVELOPMENT.i1Probability =
IF (DEVELOPMENT.SUMAt0<DEVELOPMENT.SUMAt1)
OR (DEVELOPMENT.SUMAt0+DEVELOPMENT.SUMAt1=4)
THEN (DEVELOPMENT.Tech_Advances)
ELSE(0)
: f DEVELOPMENT.Successful_D = DEVELOPMENT.Development.Potential*DEVELOPMENT.i1Probability
: f DEVELOPMENT.Out_i1 = DEVELOPMENT.NDi1
: c INNOVATION_MANAGEMENT.Bio_Prob_Range =
IF INNOVATION_MANAGEMENT.Bio_Prob > 100
THEN 100
ELSE INNOVATION_MANAGEMENT.Bio_Prob
: c DEVELOPMENT.Bio_MCPProb = MONTECARLO(INNOVATION_MANAGEMENT.Bio_Prob_Range)
: c INNOVATION_MANAGEMENT.HS_Prob_Range =
IF INNOVATION_MANAGEMENT.HS_Prob > 100
THEN 100
ELSE INNOVATION_MANAGEMENT.HS_Prob
: c DEVELOPMENT.HS_MCPProb = MONTECARLO(INNOVATION_MANAGEMENT.HS_Prob_Range)
: c DEVELOPMENT.Mkt_Prob =
IF (DEVELOPMENT.Bio_MCPProb+DEVELOPMENT.HS_MCPProb)=2
THEN 1
ELSE 0

```

DOCUMENT: Studies have found that only around 40% of the products developed reach the market level due to stringent regulatory requirements, which can be translated into an almost 40% chance per period that the developed product creates a new market. In this case biosafety and innocuous review procedures required by the government will create an indirect “tax” on the industry. Yet, this tax does not come back to the government but instead stays as a fund that increases (or decrease) the probability of approval as it changes. The biosafety factor then use the same procedure followed for the change in the “Bio Effect” so that the Montecarlo probability changes overtime as the industry either pays more or less for biosafety requirements. This way the chance of being approved increases as a biosafety culture increases. This also works for the Govt, since the more production the greater the biosafety pay and the less the natural resources depleted (win-win situation).

: f DEVELOPMENT.To.Market = DEVELOPMENT.Out.i1*DEVELOPMENT.Mkt.Prob

DOCUMENT: Being this an analysis from the POV of the central planner it is assumed that competing markets/developers are constantly developing new innovations not withstanding those already in the market. The innovator/follower approach presented in the business management literature is overviewed.

: c RESOURCE.MANAGEMENT.eD2M = EXP(DEVELOPMENT.To.Market)

: c RESOURCE.MANAGEMENT.eTD2M =

IF RESOURCE.MANAGEMENT.eD2M = 1

THEN 0

ELSE RESOURCE.MANAGEMENT.eD2M

: c RESOURCE.MANAGEMENT.Inital.Income =

(DELAY(RESOURCE.MANAGEMENT.eTD2M,1))*RESOURCE.MANAGEMENT.D.Price

: c RESOURCE.MANAGEMENT.FI1 =

(0.5*RESOURCE.MANAGEMENT.Inital.Income*((1+RESOURCE.MANAGEMENT.r)^(-1)))

DOCUMENT: This process means that whenever a product reaches the market, the developer gets three years of income. Yet, the level of this income decreases over time.

: c RESOURCE.MANAGEMENT.FI2 =

(0.25*RESOURCE.MANAGEMENT.FI1)*((1+RESOURCE.MANAGEMENT.r)^(-2))

: c RESOURCE.MANAGEMENT.FI3 =

(0.1*RESOURCE.MANAGEMENT.FI2)*((1+RESOURCE.MANAGEMENT.r)^(-3))

: c RESOURCE.MANAGEMENT.Capital.D =

RESOURCE.MANAGEMENT.Inital.Income+RESOURCE.MANAGEMENT.FI1+

RESOURCE.MANAGEMENT.FI2+RESOURCE.MANAGEMENT.FI3

DOCUMENT: In this case the capital that development produces is generated by the principal innovation (the rate that “To Market” produces at time “n”) multiplied by the price, plus the present value of the returns that this principal will bring to the sector in the following three years before the innovation’s market value reaches zero (the value loss is assumed to be 50% of the initial value after a year, 25% of that value at year two, 10% percent of that value at year three, and zero at year four). These figures are then summed at time “n.”

: c RESOURCE.MANAGEMENT.AnnD =

(RESOURCE.MANAGEMENT.TeA1D*RESOURCE.MANAGEMENT.D.Price)*

RESOURCE.MANAGEMENT.Royalty_Level

DOCUMENT: In the model, as happens in the information sector, there is no possible way of knowing beforehand if the use of the licensed IP will produce returns beforehand. The option considered here is an annuity for information/knowledge at current prices for the time the IPRs are enforceable. This is then brought to present value to produce the income for R coming from licensing.

: c RESOURCE.MANAGEMENT.AnnDPV =

DEVELOPMENT.Mkt.Prob*

PV(RESOURCE_MANAGEMENT.r,R&D_POLICY.Length, -RESOURCE_MANAGEMENT.AnnD, 0)

DOCUMENT: This is the PV of an annuity of 0.04% of the principal (the figure found at time “n”) for a period of 20 years if the product reaches the market (it has a probability of doing so of “Prob”).That figure is added to the principal (the previous total “Licensing Rate”) at the time when it was found and brought to present value at time zero.

: c RESOURCE_MANAGEMENT.From.Licencing_D = RESOURCE_MANAGEMENT.AnnDPV

DOCUMENT: The amount of financial resources going back to research per period is composed by the actual licensing rate level at time “n” (which is vaulted in Knowledge Units, A1), plus the present value (PV) of the annual royalty annuity from licensing at time “n,” if the innovation reaches the market (this is why it is multiplied by “Prob”).

: c INNOVATION_MANAGEMENT.Y.Dev.Pay =

IF NOT(RESOURCE_MANAGEMENT.Capital.D=0) AND RESOURCE_MANAGEMENT.Capital.D<1000

THEN ((0.5*R&D_POLICY.Biosafety_Level)*RESOURCE_MANAGEMENT.Capital.D)

ELSE R&D_POLICY.Biosafety_Level*RESOURCE_MANAGEMENT.Capital.D

: c INNOVATION_MANAGEMENT.N.Dev.Pay =

IF RESOURCE_MANAGEMENT.Capital.D=0

THEN (0*R&D_POLICY.Biosafety_Level*RESOURCE_MANAGEMENT.Capital.D)

ELSE INNOVATION_MANAGEMENT.Y.Dev.Pay

: f INNOVATION_MANAGEMENT.In.Bio.Ind = INNOVATION_MANAGEMENT.N.Dev.Pay

: c INNOVATION_MANAGEMENT.Y.Dev_HS.Pay =

IF NOT(RESOURCE_MANAGEMENT.Capital.D=0) AND RESOURCE_MANAGEMENT.Capital.D<1000

THEN (0.5*R&D_POLICY.Health_Safe_Rate*RESOURCE_MANAGEMENT.Capital.D)

ELSE RESOURCE_MANAGEMENT.Capital.D*R&D_POLICY.Health_Safe_Rate

: c INNOVATION_MANAGEMENT.N.Dev_HS.Pay =

IF (RESOURCE_MANAGEMENT.Capital.D=0)

THEN (0*R&D_POLICY.Health_Safe_Rate*RESOURCE_MANAGEMENT.Capital.D)

ELSE INNOVATION_MANAGEMENT.Y.Dev_HS.Pay

: f INNOVATION_MANAGEMENT.In_HS.Fund = INNOVATION_MANAGEMENT.N.Dev_HS.Pay

: c RESOURCE_MANAGEMENT.PreTax_Kd =

((RESOURCE_MANAGEMENT.Capital.D-RESOURCE_MANAGEMENT.From.Licencing_D)-

INNOVATION_MANAGEMENT.In.Bio.Ind)-INNOVATION_MANAGEMENT.In_HS.Fund)

: c RESOURCE_MANAGEMENT.Fiscal.InD =

IF RESOURCE_MANAGEMENT.PreTax_Kd <0

THEN 0

ELSE RESOURCE_MANAGEMENT.PreTax_Kd*R&D_POLICY.Tax_Rate

: f RESOURCE_MANAGEMENT.In.TT_from.D = RESOURCE_MANAGEMENT.From.Licencing_D

DOCUMENT: TTF= Technology transfer funds from development to research derived from licensing.

: f RESOURCE_MANAGEMENT.Out.TT_From.D = RESOURCE_MANAGEMENT.TechT_RtoD

DOCUMENT: This fraction is due to the patent regulation existing in Spain operating in a similar way to the Bayh-Dole act requiring this allocation of resources between these three elements. It is assumed that this income division only affects the licensing of patents to research, since these are mostly funded by government funding and the information necessary for these is developed within public research centers. The “Royalty Rule” switch is introduced to differentiate the model’s approach for Mexico -which does not have such rule- from that of Spain.

: f RESOURCE_MANAGEMENT.TTRD_to_Govt =

IF RESOURCE_MANAGEMENT.Royalty_Rule =1

```

THEN (RESOURCE_MANAGEMENT.Out_TT_From_D*RESOURCE_MANAGEMENT.TTD_Frac)
ELSE 0
: f INNOVATION_MANAGEMENT.Bio_Ind_to_Govt =
IF DEVELOPMENT.Successful_D>0
THEN INNOVATION_MANAGEMENT.Biosafety_Review_Costs
ELSE 0
: f RESOURCE_MANAGEMENT.TTRD_to_R =
IF RESOURCE_MANAGEMENT.Royalty_Rule = 1
THEN (RESOURCE_MANAGEMENT.Out_TT_From_D*RESOURCE_MANAGEMENT.TTD_Frac)
ELSE RESOURCE_MANAGEMENT.Out_TT_From_D*0.8
: c RESOURCE_MANAGEMENT.AnnR =
(RESOURCE_MANAGEMENT.TeA1R*RESOURCE_MANAGEMENT.D_Price)*
RESOURCE_MANAGEMENT.Royalty_Level
: c RESOURCE_MANAGEMENT.AnnRPV =
INNOVATION_MANAGEMENT.Match_Type_2*
PV(RESOURCE_MANAGEMENT.r, R&D_POLICY.Length, -RESOURCE_MANAGEMENT.AnnR, 0)
: c RESOURCE_MANAGEMENT.From_Licensing_R = RESOURCE_MANAGEMENT.AnnRPV
: f RESOURCE_MANAGEMENT.In_TT_from_R = RESOURCE_MANAGEMENT.From_Licensing_R
: f RESOURCE_MANAGEMENT.Out_TT_From_R = RESOURCE_MANAGEMENT.TechT_RtoR
: f RESOURCE_MANAGEMENT.TTRR_To_R =
RESOURCE_MANAGEMENT.Out_TT_From_R*RESOURCE_MANAGEMENT.TTF_R_Fraction
: f RESOURCE_MANAGEMENT.In_ResR =
(RESOURCE_MANAGEMENT.TTRD_to_R+RESOURCE_MANAGEMENT.TTRR_To_R)
: f RESOURCE_MANAGEMENT.Out_NetFinR = RESOURCE_MANAGEMENT.NetFin_ResR
: f RESOURCE_MANAGEMENT.In_R_Inc = RESOURCE_MANAGEMENT.Out_NetFinR
: f RESOURCE_MANAGEMENT.Out_R_Inc = RESOURCE_MANAGEMENT.R_Income
: f RESOURCE_MANAGEMENT.In_R_Save =
RESOURCE_MANAGEMENT.Out_R_Inc*RESOURCE_MANAGEMENT.Save_Rate
: f RESOURCE_MANAGEMENT.Out_R_Save = RESOURCE_MANAGEMENT.R_Save
DOCUMENT: These are assumed to be resources going back to the government, who originally provided them.
: f RESOURCE_MANAGEMENT.In_Res_Govt =
IF RESOURCE_MANAGEMENT.FixR&D_Fund_Switch = 1
THEN (RESOURCE_MANAGEMENT.FixedGovt_Fund+
(RESOURCE_MANAGEMENT.Fiscal_InD+
RESOURCE_MANAGEMENT.TTRD_to_Govt+
INNOVATION_MANAGEMENT.Bio_Ind_to_Govt+
RESOURCE_MANAGEMENT.Out_R_Save+
RESOURCE_MANAGEMENT.Risk_Free_Comp))
ELSE RESOURCE_MANAGEMENT.Fiscal_InD+
RESOURCE_MANAGEMENT.TTRD_to_Govt+
INNOVATION_MANAGEMENT.Bio_Ind_to_Govt+
RESOURCE_MANAGEMENT.Out_R_Save+
RESOURCE_MANAGEMENT.Risk_Free_Comp
: f RESOURCE_MANAGEMENT.Out_Res_Govt = RESOURCE_MANAGEMENT.Net_Res_Govt

```

```

: f RESOURCE.MANAGEMENT.In.Govt_R =
RESOURCE.MANAGEMENT.Out.Res.Govt*R&D.POLICY.R&D.Rate
: f RESOURCE.MANAGEMENT.Out.Govt_R = RESOURCE.MANAGEMENT.Govt_R
: f RESOURCE.MANAGEMENT.Out.VCtoR = RESOURCE.MANAGEMENT.VCtoR
: c RESEARCH.Kr = 1+RESOURCE.MANAGEMENT.Out.Govt_R+RESOURCE.MANAGEMENT.Out.VCtoR
DOCUMENT: K is multiplied by a fraction of A1 (information) because information is capital. In this model each unit
of capital is worth two units of information.
: c RESOURCE.MANAGEMENT.GRDep% = RESOURCE.MANAGEMENT.GeneDep_Rate/100
: f RESOURCE.MANAGEMENT.In.Gene_Res =
RESOURCE.MANAGEMENT.Gene_Res*RESOURCE.MANAGEMENT.Gene.Prospect
: f RESOURCE.MANAGEMENT.Out.Gene_Res =
RESOURCE.MANAGEMENT.Gene_Res*RESOURCE.MANAGEMENT.GRDep%
: f RESEARCH.Input_R = LOGN(RESEARCH.HCr+RESEARCH.Kr+RESOURCE.MANAGEMENT.Out.Gene_Res)
: f RESEARCH.Output_R = RESEARCH.Research.Potential
: f DEVELOPMENT.Output_D = DEVELOPMENT.Development.Potential
: f RESOURCE.MANAGEMENT.In.BioLab =
RESOURCE.MANAGEMENT.Biotech_Labor*RESOURCE.MANAGEMENT.G_Rate
: f RESOURCE.MANAGEMENT.Out.BioLab =
RESOURCE.MANAGEMENT.Biotech_Labor*RESOURCE.MANAGEMENT.D_Rate
: c RESOURCE.MANAGEMENT.Dev_Effect5 =
IF NOT(INNOVATION.MANAGEMENT.Bio_Ind_Res>5000000) AND INNOVATION.MANAGEMENT.Bio_Ind_Res
> 1000000
THEN 0.01*RESOURCE.MANAGEMENT.Bio_Effect.Change
ELSE 0
: c RESOURCE.MANAGEMENT.Dev_Effect4 =
IF NOT(INNOVATION.MANAGEMENT.Bio_Ind_Res>8500000) AND INNOVATION.MANAGEMENT.Bio_Ind_Res
> 5000000
THEN 0.1*RESOURCE.MANAGEMENT.Bio_Effect.Change
ELSE RESOURCE.MANAGEMENT.Dev_Effect5
: c RESOURCE.MANAGEMENT.Dev_Effect3 =
IF NOT (INNOVATION.MANAGEMENT.Bio_Ind_Res>9000000) AND INNOVATION.MANAGEMENT.Bio_Ind_Res
> 8500000
THEN RESOURCE.MANAGEMENT.Bio_Effect.Change*0.25
ELSE RESOURCE.MANAGEMENT.Dev_Effect4
: c RESOURCE.MANAGEMENT.Dev_Effect2 =
IF NOT( INNOVATION.MANAGEMENT.Bio_Ind_Res>10000000 OR INNOVATION.MANAGEMENT.Bio_Ind_Res=0)
AND INNOVATION.MANAGEMENT.Bio_Ind_Res>9000000
THEN RESOURCE.MANAGEMENT.Bio_Effect.Change*0.5
ELSE RESOURCE.MANAGEMENT.Dev_Effect3
: c RESOURCE.MANAGEMENT.Dev_Effect1 =
IF INNOVATION.MANAGEMENT.Bio_Ind_Res >10000000
THEN RESOURCE.MANAGEMENT.Bio_Effect.Change
ELSE RESOURCE.MANAGEMENT.Dev_Effect2
: c RESOURCE.MANAGEMENT.Dev_Effect0 =

```

```

IF INNOVATION_MANAGEMENT.Bio_Ind_Res =0
THEN RESOURCE_MANAGEMENT.Bio_Effect_Change*INNOVATION_MANAGEMENT.Bio_Ind_Res
ELSE RESOURCE_MANAGEMENT.Dev_Effect1
: c RESOURCE_MANAGEMENT.If_Change =
IF RESOURCE_MANAGEMENT.Dev_Effect0 >0
THEN RESOURCE_MANAGEMENT.Dev_Effect0
ELSE 0
: f RESOURCE_MANAGEMENT.In_DR =
IF RESOURCE_MANAGEMENT.If_Change>0
THEN RESOURCE_MANAGEMENT.Depletion_Rate-RESOURCE_MANAGEMENT.If_Change
ELSE RESOURCE_MANAGEMENT.Depletion_Rate+RESOURCE_MANAGEMENT.If_No_Change
DOCUMENT: If there are no "Biosafety Industry Resources" then depletion "Factor" increases 0.05, if "BIR" is positive
within a range then "Factor" decreases (depending on the level: 0<BIR<1000 then the "Bio Effect Change" (0.5) is al-
tered by either a factor of 50%, 25%, 10%, or 0).
: f RESOURCE_MANAGEMENT.Out_DR = RESOURCE_MANAGEMENT.Depletion_Rate
: f RESOURCE_MANAGEMENT.TTRD_to_R_Infra =
IF RESOURCE_MANAGEMENT.Royalty_Rule=1
THEN (RESOURCE_MANAGEMENT.Out_TT_From_D*RESOURCE_MANAGEMENT.TTD_Frac)
ELSE RESOURCE_MANAGEMENT.Out_TT_From_D*0.20
: f RESOURCE_MANAGEMENT.TTRR_To_R_Infra =
RESOURCE_MANAGEMENT.Out_TT_From_R*(1-RESOURCE_MANAGEMENT.TTF_R_Fraction)
: f RESOURCE_MANAGEMENT.In_Govt_Infra = RESOURCE_MANAGEMENT.Out_Res_Govt*R&D.POLICY.Infra_Rate
: f RESOURCE_MANAGEMENT.Out_Govt_Infra = RESOURCE_MANAGEMENT.Govt_Infra
: f RESOURCE_MANAGEMENT.In_BR_Infra =
(RESOURCE_MANAGEMENT.TTRD_to_R_Infra+
RESOURCE_MANAGEMENT.TTRR_To_R_Infra+RESOURCE_MANAGEMENT.Out_Govt_Infra)
: f RESOURCE_MANAGEMENT.Out_BR_Infra = RESOURCE_MANAGEMENT.BR_Infra_Res
: f RESOURCE_MANAGEMENT.In_D_Inc =
RESOURCE_MANAGEMENT.Out_Net_FIn_D-RESOURCE_MANAGEMENT.In_D_Reinv
: f RESOURCE_MANAGEMENT.Out_D_Inc = RESOURCE_MANAGEMENT.D_Income
: f RESOURCE_MANAGEMENT.Out_D_Reinv = RESOURCE_MANAGEMENT.D_Reinvest
: c RESOURCE_MANAGEMENT.Dif_VCR_Res =
RESOURCE_MANAGEMENT.VCR_Fund-RESOURCE_MANAGEMENT.VCtoR_Debt
: f RESOURCE_MANAGEMENT.In_VCRD_Bal =
IF RESOURCE_MANAGEMENT.Dif_VCR_Res<0
THEN (-1*RESOURCE_MANAGEMENT.Dif_VCR_Res)
ELSE 0
: f RESOURCE_MANAGEMENT.Out_VCRD_Bal = RESOURCE_MANAGEMENT.VCRD_Bal
: f RESOURCE_MANAGEMENT.In_VCRF_Bal = RESOURCE_MANAGEMENT.Dif_VCR_Res
: f RESOURCE_MANAGEMENT.Out_VCRF_Bal = RESOURCE_MANAGEMENT.VCRF_Bal
: f RESOURCE_MANAGEMENT.In_D_Save =
RESOURCE_MANAGEMENT.Out_D_Inc*RESOURCE_MANAGEMENT.Save_Rate
: f RESOURCE_MANAGEMENT.In_D_Spend =
RESOURCE_MANAGEMENT.Out_D_Inc-RESOURCE_MANAGEMENT.In_D_Save

```

```

: f RESOURCE_MANAGEMENT.Out_D.Spend = RESOURCE_MANAGEMENT.D.Spend
: f RESOURCE_MANAGEMENT.Out_D.Save = RESOURCE_MANAGEMENT.D.Save
: f RESOURCE_MANAGEMENT.In_R.Spend =
RESOURCE_MANAGEMENT.Out_R.Inc-RESOURCE_MANAGEMENT.In_R.Save
: f RESOURCE_MANAGEMENT.Out_R.Spend = RESOURCE_MANAGEMENT.R.Spend
: f RESOURCE_MANAGEMENT.In.Spend =
RESOURCE_MANAGEMENT.Out_D.Spend+RESOURCE_MANAGEMENT.Out_R.Spend
: f RESOURCE_MANAGEMENT.Out.Spend = RESOURCE_MANAGEMENT.All.Spend
: f RESOURCE_MANAGEMENT.In.Save =
RESOURCE_MANAGEMENT.Out_R.Save+RESOURCE_MANAGEMENT.Out_D.Save
: f RESOURCE_MANAGEMENT.To_Invest = RESOURCE_MANAGEMENT.All.Save
: c RESOURCE_MANAGEMENT.RtoD2 =
IF RESOURCE_MANAGEMENT.Available_Lr < INNOVATION_MANAGEMENT.R.Infra_L.Capacity
THEN (+1*RESOURCE_MANAGEMENT.Change_%LR)
ELSE 0
: c RESOURCE_MANAGEMENT.RtoD1 =
IF RESOURCE_MANAGEMENT.Available_Lr > INNOVATION_MANAGEMENT.R.Infra_L.Capacity
THEN (-1*RESOURCE_MANAGEMENT.Change_%LR)
ELSE RESOURCE_MANAGEMENT.RtoD2
: c RESOURCE_MANAGEMENT.RtoD_Arbit =
IF RESOURCE_MANAGEMENT.Available_Lr = INNOVATION_MANAGEMENT.R.Infra_L.Capacity
THEN 0
ELSE RESOURCE_MANAGEMENT.RtoD1
: f RESOURCE_MANAGEMENT.In_RD%Mob =
RESOURCE_MANAGEMENT.RtoD_Arbit+RESOURCE_MANAGEMENT.RtoD_%Mob
: f RESOURCE_MANAGEMENT.Out_RD%Mob = RESOURCE_MANAGEMENT.RtoD_%Mob
: c RESOURCE_MANAGEMENT.Invest_Rule_YVC = RESOURCE_MANAGEMENT.To_Invest
: c RESOURCE_MANAGEMENT.VC_Change =
IF RESOURCE_MANAGEMENT.Out_VCtoR>0
OR RESOURCE_MANAGEMENT.Out_VCtoD>0
THEN (RESOURCE_MANAGEMENT.VC%+0.01)
ELSE (RESOURCE_MANAGEMENT.VC%-0.001)
: c RESOURCE_MANAGEMENT.VC_Invest = RESOURCE_MANAGEMENT.VC_Change
DOCUMENT: This is the percentage of the total "To Investment" rate that goes to VC instead of "Risk Free Investment."
: f RESOURCE_MANAGEMENT.To_VC =
IF RESOURCE_MANAGEMENT.VC_Switch=1
THEN (RESOURCE_MANAGEMENT.Invest_Rule_YVC*RESOURCE_MANAGEMENT.VC_Invest)
ELSE 0
: c RESOURCE_MANAGEMENT.Invest_Rule_NVC = RESOURCE_MANAGEMENT.To_Invest
: f RESOURCE_MANAGEMENT.To_Risk_Free =
IF RESOURCE_MANAGEMENT.VC_Switch=1
THEN (RESOURCE_MANAGEMENT.Invest_Rule_YVC-RESOURCE_MANAGEMENT.To_VC)
ELSE RESOURCE_MANAGEMENT.Invest_Rule_NVC
: f RESOURCE_MANAGEMENT.To_Compound =

```

```

RESOURCE_MANAGEMENT.Risk_Free_Inv+
RESOURCE_MANAGEMENT.Risk_Free_Comp*CGROWTH((100*RESOURCE_MANAGEMENT.r))
: c RESOURCE_MANAGEMENT.Kr_Delay = DELAY(RESEARCH.Kr,1)
: c RESOURCE_MANAGEMENT.VCR =
IF RESOURCE_MANAGEMENT.NetFin_ResR>(RESOURCE_MANAGEMENT.Kr_Delay*RESOURCE_MANAGEMENT.r)
THEN 1
ELSE 0
DOCUMENT: Here, VC investors will risk their resources if the levels of income displayed by the sector are above those
that the natural interest rate would offer, meaning they will be able to collect at least as much as they would if they
were investing on risk free options. (instead of having "IF Net.Financial_Reources_(R,D) > Kr. Delay (5) THEN 1 ELSE
0, comparing the net returns today with investment levels five years ago).
: c RESOURCE_MANAGEMENT.Kd_Delay = DELAY(DEVELOPMENT.Kd,1)
: c RESOURCE_MANAGEMENT.VCD =
IF RESOURCE_MANAGEMENT.NetFin_ResD>(RESOURCE_MANAGEMENT.Kd_Delay*RESOURCE_MANAGEMENT.r)
THEN 1
ELSE 0
: c RESOURCE_MANAGEMENT.VC4 =
IF RESOURCE_MANAGEMENT.VCR=0 AND RESOURCE_MANAGEMENT.VCD=0
THEN 1
ELSE 0
: c RESOURCE_MANAGEMENT.VC3 =
IF RESOURCE_MANAGEMENT.VCD=0 AND RESOURCE_MANAGEMENT.VCR=1
THEN 2
ELSE RESOURCE_MANAGEMENT.VC4
: c RESOURCE_MANAGEMENT.VC2 =
IF RESOURCE_MANAGEMENT.VCR=0 AND RESOURCE_MANAGEMENT.VCD = 1
THEN 3
ELSE RESOURCE_MANAGEMENT.VC3
: c RESOURCE_MANAGEMENT.VC1 =
IF RESOURCE_MANAGEMENT.VCR AND RESOURCE_MANAGEMENT.VCD = 1
THEN 4
ELSE RESOURCE_MANAGEMENT.VC2
: f RESOURCE_MANAGEMENT.Out_VC =
IF (RESOURCE_MANAGEMENT.VC1=4 OR RESOURCE_MANAGEMENT.VC1=3 OR RESOURCE_MANAGEMENT.VC1=2)
AND RESOURCE_MANAGEMENT.VC_Switch=1
THEN (RESOURCE_MANAGEMENT.VC_Total*RESOURCE_MANAGEMENT.VC_Invest_Rate)
ELSE 0
: c RESOURCE_MANAGEMENT.From_VCRD_Bal = RESOURCE_MANAGEMENT.In_VCRD_Bal
DOCUMENT: This parameter represents the following amount:
: f RESOURCE_MANAGEMENT.In_VCR_Debt =
RESOURCE_MANAGEMENT.Out_VCtoR+RESOURCE_MANAGEMENT.From_VCRD_Bal
: f RESOURCE_MANAGEMENT.Out_VCR_Debt = RESOURCE_MANAGEMENT.VCtoR_Debt
: c RESOURCE_MANAGEMENT.Dif_VCD_Res =
RESOURCE_MANAGEMENT.VCD_Fund-RESOURCE_MANAGEMENT.VCtoD_Debt

```

```

: f RESOURCE_MANAGEMENT.In.VCDD_Bal =
IF RESOURCE_MANAGEMENT.Dif.VCD_Res<0
THEN (-1*RESOURCE_MANAGEMENT.Dif.VCD_Res)
ELSE 0
: c RESOURCE_MANAGEMENT.From.VCDD_Bal = RESOURCE_MANAGEMENT.In.VCDD_Bal
: f RESOURCE_MANAGEMENT.In.VCD_Debt =
RESOURCE_MANAGEMENT.Out.VCtoD+RESOURCE_MANAGEMENT.From.VCDD_Bal
: f RESOURCE_MANAGEMENT.Out.VCD_Debt = RESOURCE_MANAGEMENT.VCtoD_Debt
: f RESOURCE_MANAGEMENT.In.VCDF_Bal = RESOURCE_MANAGEMENT.Dif.VCD_Res
: c RESOURCE_MANAGEMENT.From.VCDF_Bal = RESOURCE_MANAGEMENT.In.VCDF_Bal
: f RESOURCE_MANAGEMENT.In.VCD_Fund =
(RESOURCE_MANAGEMENT.In.D_Inc*RESOURCE_MANAGEMENT.D_Debt_Rate)
+RESOURCE_MANAGEMENT.From.VCDF_Bal

```

DOCUMENT: The parameter that captures the debt rate times the Income represents the amount of financial resources available to support VC investment, it is not an actual capital flow (reason why these are not actually discounted from the inflow of income coming to either R or D). The actual physical resources are those coming from the VCR and VCD funds balance.

```

: f RESOURCE_MANAGEMENT.Out.VCD_Fund = RESOURCE_MANAGEMENT.VCD_Fund
: c RESOURCE_MANAGEMENT.From.VCRF_Bal = RESOURCE_MANAGEMENT.In.VCRF_Bal
: f RESOURCE_MANAGEMENT.In.VCR_Fund =
(RESOURCE_MANAGEMENT.R_Debt_Rate*RESOURCE_MANAGEMENT.In.R_Inc)
+RESOURCE_MANAGEMENT.From.VCRF_Bal

```

DOCUMENT: Debt rate is the maximum amount of income allowed to be allocated towards paying debt. In other words, it is the maximum leverage level that a sector can leverage its own income.

```

: f RESOURCE_MANAGEMENT.Out.VCR_Fund = RESOURCE_MANAGEMENT.VCR_Fund
: f RESOURCE_MANAGEMENT.Out.VCDD_Bal = RESOURCE_MANAGEMENT.VCDD_Bal
: f RESOURCE_MANAGEMENT.Out.VCDF_Bal = RESOURCE_MANAGEMENT.VCDF_Bal
: c RESOURCE_MANAGEMENT.Out.Restriction =

```

```

IF NOT (RESOURCE_MANAGEMENT.VC1=2 OR RESOURCE_MANAGEMENT.VC1=3
OR RESOURCE_MANAGEMENT.VC1=4)

```

```

THEN 0

```

```

ELSE 1

```

DOCUMENT: This restriction allows the flow of VC into projects only when the matching mechanism is available. In other words, only when VC1 is equal to 2, 3 or 4, and not when there is no match, as in VC1=1.

```

: f RESOURCE_MANAGEMENT.In.Intl_VC = RESOURCE_MANAGEMENT.Intl_VC_Invest
: f RESOURCE_MANAGEMENT.Out.Intl_VC =
(RESOURCE_MANAGEMENT.Intl_VC_Fund*RESOURCE_MANAGEMENT.Intl_VC_Invest_Rate)*
RESOURCE_MANAGEMENT.Out.Restriction

```

```

: c RESEARCH.HCt0 = DELAY(RESEARCH.HCr,1)

```

```

: c RESEARCH.ProbHC =

```

```

(RESEARCH.Degree_HC+(RESEARCH.Degree_HC*((RESEARCH.HCr/RESEARCH.HCt0)-1)))

```

```

: c RESEARCH.ProbHC_Range = IF RESEARCH.ProbHC>100 THEN 100 ELSE RESEARCH.ProbHC

```

```

: c RESEARCH.MTCHCr = MONTECARLO(RESEARCH.ProbHC_Range)

```

```

: c RESEARCH.Kt0 = DELAY(RESEARCH.Kr,1)

```

```

: c RESEARCH.ProbK = (RESEARCH.Degree_K+(RESEARCH.Degree_K*((RESEARCH.Kr/RESEARCH.Kt0)-1)))
: c RESEARCH.ProbK.Range = IF RESEARCH.ProbK>100 THEN 100 ELSE RESEARCH.ProbK
DOCUMENT: This step is to keep the change within the Montecarlo 0 to 100 range. Some of the values are beyond 100
and thus have to be standardized to the range.
: c RESEARCH.MTCKr = MONTECARLO(RESEARCH.ProbK.Range)
: c RESEARCH.SUMAt1 = RESEARCH.MTCHCr+RESEARCH.MTCKr
: c RESEARCH.SUMAt0 = DELAY(RESEARCH.SUMAt1,1)
: c RESEARCH.A1Probability =
IF (RESEARCH.SUMAt0<RESEARCH.SUMAt1)
OR (RESEARCH.SUMAt0+RESEARCH.SUMAt1=4)
THEN (RESEARCH.Tech_Advances)
ELSE 0
: f RESEARCH.Successful_R = RESEARCH.Research.Potential*RESEARCH.A1Probability
: c RESOURCE_MANAGEMENT.eSuccess_R = EXP(RESEARCH.Successful_R)
: c RESOURCE_MANAGEMENT.Gene_Effect_Change =
RESOURCE_MANAGEMENT.Access_Gene_Res*R&D.POLICY.Breadth_Fact
: c RESOURCE_MANAGEMENT.R.Effect5 =
IF NOT(RESOURCE_MANAGEMENT.eSuccess_R>1000000) AND RESOURCE_MANAGEMENT.eSuccess_R > 1
THEN 0.01*RESOURCE_MANAGEMENT.Gene_Effect_Change
ELSE 0
: c RESOURCE_MANAGEMENT.R.Effect4 =
IF NOT(RESOURCE_MANAGEMENT.eSuccess_R>2000000) AND RESOURCE_MANAGEMENT.eSuccess_R > 1000000
THEN 0.1*RESOURCE_MANAGEMENT.Gene_Effect_Change
ELSE RESOURCE_MANAGEMENT.R.Effect5
: c RESOURCE_MANAGEMENT.R.Effect3 =
IF NOT (RESOURCE_MANAGEMENT.eSuccess_R>5000000) AND RESOURCE_MANAGEMENT.eSuccess_R >
2000000
THEN RESOURCE_MANAGEMENT.Gene_Effect_Change*0.25
ELSE RESOURCE_MANAGEMENT.R.Effect4
: c RESOURCE_MANAGEMENT.R.Effect2 =
IF NOT( RESOURCE_MANAGEMENT.eSuccess_R>10000000 OR RESOURCE_MANAGEMENT.eSuccess_R=0) AND
RESOURCE_MANAGEMENT.eSuccess_R>5000000
THEN RESOURCE_MANAGEMENT.Gene_Effect_Change*0.5
ELSE RESOURCE_MANAGEMENT.R.Effect3
: c RESOURCE_MANAGEMENT.R.Effect1 =
IF RESOURCE_MANAGEMENT.eSuccess_R >10000000
THEN RESOURCE_MANAGEMENT.Gene_Effect_Change
ELSE RESOURCE_MANAGEMENT.R.Effect2
: c RESOURCE_MANAGEMENT.R.Effect0 =
IF RESOURCE_MANAGEMENT.eSuccess_R =0
THEN RESOURCE_MANAGEMENT.Gene_Effect_Change*RESOURCE_MANAGEMENT.eSuccess_R
ELSE RESOURCE_MANAGEMENT.R.Effect1
: c RESOURCE_MANAGEMENT.If_R_Change =
IF RESOURCE_MANAGEMENT.R.Effect0 >0

```

```

THEN RESOURCE_MANAGEMENT.R_Effect0
ELSE 0
: f RESOURCE_MANAGEMENT.In_GR_Dep =
IF RESOURCE_MANAGEMENT.If_R_Change>0
THEN RESOURCE_MANAGEMENT.GeneDep_Rate-RESOURCE_MANAGEMENT.If_R_Change
ELSE RESOURCE_MANAGEMENT.GeneDep_Rate+RESOURCE_MANAGEMENT.If_No_R_Change
DOCUMENT: If there are no "Biosafety Industry Resources" then depletion "Factor" increases 0.05, if "BIR" is positive
within a range then "Factor" decreases (depending on the level: 0<BIR<1000 then the "Bio Effect Change" (0.5) is al-
tered by either a factor of 50%, 25%, 10%, or 0).
: f RESOURCE_MANAGEMENT.Out_GR_Dep = RESOURCE_MANAGEMENT.GeneDep_Rate
: c R&D_POLICY.PubDep_Thres = R&D_POLICY.Intl_Bio_Standard
: c R&D_POLICY.Public_Perception = RESOURCE_MANAGEMENT.Depletion_Rate-R&D_POLICY.PubDep_Thres
: c R&D_POLICY.PP_Effect =
IF R&D_POLICY.Public_Perception>0
THEN 0.01
ELSE 0
: f R&D_POLICY.In_BLev =
IF (R&D_POLICY.Biosafety_Level+R&D_POLICY.PP_Effect) > R&D_POLICY.Intl_Bio_Standard
THEN ((R&D_POLICY.Biosafety_Level+R&D_POLICY.PP_Effect)-1)
ELSE (R&D_POLICY.Biosafety_Level+R&D_POLICY.PP_Effect)
: f R&D_POLICY.Out_BLev = R&D_POLICY.Biosafety_Level
: c R&D_POLICY.T2 =
IF RESOURCE_MANAGEMENT.Net_Res_Govt<10000
THEN (-1*R&D_POLICY.Tax_Rater_Change)
ELSE 0
: c R&D_POLICY.T1 =
IF RESOURCE_MANAGEMENT.Net_Res_Govt> 1000000
THEN (R&D_POLICY.Tax_Rater_Change)
ELSE R&D_POLICY.T2
: f R&D_POLICY.In_Tax_Change = R&D_POLICY.Tax_Rate+R&D_POLICY.T1
: f R&D_POLICY.Out_Tax_Change = R&D_POLICY.Tax_Rate
: c R&D_POLICY.R&D2 =
IF R&D_POLICY.Tax_Rate < 0.35
THEN -1*R&D_POLICY.R_Invest_Change
ELSE 0
: c R&D_POLICY.R&D1 =
IF R&D_POLICY.Tax_Rate > 0.35
THEN R&D_POLICY.R_Invest_Change
ELSE R&D_POLICY.R&D2
: f R&D_POLICY.In_R&D_Rate = R&D_POLICY.R&D_Rate+R&D_POLICY.R&D1
: f R&D_POLICY.Out_R&D_Rate = R&D_POLICY.R&D_Rate
: f R&D_POLICY.In_HSR = R&D_POLICY.Intl_HS_Rate
: f R&D_POLICY.Out_HSR = R&D_POLICY.Health_Safe_Rate
: c R&D_POLICY.Infra2 =

```

```

IF R&D_POLICY.R&D_Rate < 0.6
THEN -1*R&D_POLICY.Infra_Invest_Change
ELSE 0
: c R&D_POLICY.Infra1 =
IF R&D_POLICY.R&D_Rate > 0.84
THEN R&D_POLICY.Infra_Invest_Change
ELSE R&D_POLICY.Infra2
: f R&D_POLICY.In_Infra_Rate = R&D_POLICY.Infra_Rate+R&D_POLICY.Infra1
: f R&D_POLICY.Out_Infra_Rate = R&D_POLICY.Infra_Rate
: c RESOURCE_MANAGEMENT.Spread =
(RESOURCE_MANAGEMENT.GRDep%-RESOURCE_MANAGEMENT.Gene_Prospect)*100
: c R&D_POLICY.Effective_App_Rate =
IF RESOURCE_MANAGEMENT.Spread > 0.25
THEN R&D_POLICY.APP_Rate_Change
ELSE 0
: f R&D_POLICY.In_BFact = R&D_POLICY.Breadth+R&D_POLICY.Effective_App_Rate
: f R&D_POLICY.Out_BFact = R&D_POLICY.Breadth_Fact
: c R&D_POLICY.Length_Fact = R&D_POLICY.Length/25
DOCUMENT: One in this converter means that the length of a patent protection is 25years. Any changes to the length
will alter the level.
: f R&D_POLICY.In_IPR =
IF (R&D_POLICY.In_BFact*R&D_POLICY.Length_Fact) <1
THEN (R&D_POLICY.In_BFact*R&D_POLICY.Length_Fact)
ELSE 1
: f R&D_POLICY.Out_IPR = R&D_POLICY.IPR_Effect
: c R&D_POLICY.HS_Change1 =
IF NOT(INNOVATION_MANAGEMENT.Health_S.Fund<10000000)
THEN (R&D_POLICY.HS_Inspect_Level-R&D_POLICY.HS_Degree)
ELSE 0
: c R&D_POLICY.HS_Change =
IF INNOVATION_MANAGEMENT.Health_S.Fund<10000000
THEN (R&D_POLICY.HS_Inspect_Level+R&D_POLICY.HS_Degree)
ELSE R&D_POLICY.HS_Change1
: f R&D_POLICY.In_HSIL = R&D_POLICY.HS_Change
: f R&D_POLICY.Out_HSIL = R&D_POLICY.HS_Inspect_Level
: f INNOVATION_MANAGEMENT.To_FreeA1 = CONVEYOR OUTFLOW
: f INNOVATION_MANAGEMENT.To_PubKnow = INNOVATION_MANAGEMENT.Free_Access_A1
: c INNOVATION_MANAGEMENT.Bio_Effect5 =
IF NOT(INNOVATION_MANAGEMENT.Bio_Ind_Res>1000000) AND INNOVATION_MANAGEMENT.Bio_Ind_Res
> 100000
THEN 0.05*INNOVATION_MANAGEMENT.Bio_Prob_Change
ELSE 0
: c INNOVATION_MANAGEMENT.Bio_Effect4 =
IF NOT(INNOVATION_MANAGEMENT.Bio_Ind_Res>2500000) AND INNOVATION_MANAGEMENT.Bio_Ind_Res

```

```

> 1000000
THEN 0.1*INNOVATION_MANAGEMENT.Bio_Prob_Change
ELSE INNOVATION_MANAGEMENT.Bio_Effect5
: c INNOVATION_MANAGEMENT.Bio_Effect3 =
IF NOT (INNOVATION_MANAGEMENT.Bio_Ind_Res>5000000) AND INNOVATION_MANAGEMENT.Bio_Ind_Res
> 2500000
THEN INNOVATION_MANAGEMENT.Bio_Prob_Change*0.25
ELSE INNOVATION_MANAGEMENT.Bio_Effect4
: c INNOVATION_MANAGEMENT.Bio_Effect2 =
IF NOT( INNOVATION_MANAGEMENT.Bio_Ind_Res>10000000 OR INNOVATION_MANAGEMENT.Bio_Ind_Res=0)
AND INNOVATION_MANAGEMENT.Bio_Ind_Res>5000000
THEN INNOVATION_MANAGEMENT.Bio_Prob_Change*0.5
ELSE INNOVATION_MANAGEMENT.Bio_Effect3
: c INNOVATION_MANAGEMENT.Bio_Effect1 =
IF INNOVATION_MANAGEMENT.Bio_Ind_Res > 10000000
THEN INNOVATION_MANAGEMENT.Bio_Prob_Change
ELSE INNOVATION_MANAGEMENT.Bio_Effect2
: c INNOVATION_MANAGEMENT.Bio_Effect =
IF INNOVATION_MANAGEMENT.Bio_Ind_Res =0
THEN INNOVATION_MANAGEMENT.Bio_Prob_Change*INNOVATION_MANAGEMENT.Bio_Ind_Res
ELSE INNOVATION_MANAGEMENT.Bio_Effect1
: c INNOVATION_MANAGEMENT.If_Change =
IF INNOVATION_MANAGEMENT.Bio_Effect >0
THEN INNOVATION_MANAGEMENT.Bio_Effect
ELSE 0
: f INNOVATION_MANAGEMENT.In_Prob =
IF INNOVATION_MANAGEMENT.If_Change > 0
THEN (INNOVATION_MANAGEMENT.Bio_Prob+INNOVATION_MANAGEMENT.If_Change)
ELSE (INNOVATION_MANAGEMENT.Bio_Prob-INNOVATION_MANAGEMENT.If_No_Change)
: f INNOVATION_MANAGEMENT.Out_Prob = INNOVATION_MANAGEMENT.Bio_Prob
: f INNOVATION_MANAGEMENT.In_R_Infra = RESOURCE_MANAGEMENT.BR_Infra_Res
DOCUMENT: Each infrastructure unit (or research center, i.e. university) is valued in 50,000 units.
: f INNOVATION_MANAGEMENT.Out_R_Infra =
INNOVATION_MANAGEMENT.R_Infra*INNOVATION_MANAGEMENT.R_Infra_Dep
: c INNOVATION_MANAGEMENT.PK_Dep = EXP(-0.02*TIME)
: c INNOVATION_MANAGEMENT.eSDC = EXP(INNOVATION_MANAGEMENT.SpillDClust)
: c INNOVATION_MANAGEMENT.eSRC = EXP(INNOVATION_MANAGEMENT.SpillRClust)
: c INNOVATION_MANAGEMENT.V4 =
IF INNOVATION_MANAGEMENT.R_Clustering = 0 AND INNOVATION_MANAGEMENT.D_Clustering = 0
THEN INNOVATION_MANAGEMENT.No_Cluster
ELSE 0
: c INNOVATION_MANAGEMENT.V3 =
IF INNOVATION_MANAGEMENT.R_Clustering = 0 AND INNOVATION_MANAGEMENT.D_Clustering = 1
THEN INNOVATION_MANAGEMENT.eSDC

```

```

ELSE INNOVATION_MANAGEMENT.V4
: c INNOVATION_MANAGEMENT.V2 =
IF INNOVATION_MANAGEMENT.R_Clustering = 1 AND INNOVATION_MANAGEMENT.D_Clustering = 0
THEN INNOVATION_MANAGEMENT.eSRC
ELSE INNOVATION_MANAGEMENT.V3
: c INNOVATION_MANAGEMENT.V1 =
IF INNOVATION_MANAGEMENT.R_Clustering = 1 AND INNOVATION_MANAGEMENT.D_Clustering = 1
THEN (INNOVATION_MANAGEMENT.eSDC+INNOVATION_MANAGEMENT.eSRC)
ELSE INNOVATION_MANAGEMENT.V2
: c INNOVATION_MANAGEMENT.V0 =
IF INNOVATION_MANAGEMENT.V1 = 2
THEN 0
ELSE INNOVATION_MANAGEMENT.V1
: c INNOVATION_MANAGEMENT.Spillover_Effect =
IF INNOVATION_MANAGEMENT.V1= 1
THEN 0
ELSE INNOVATION_MANAGEMENT.V0
: f INNOVATION_MANAGEMENT.In_PubKnowl =
(INNOVATION_MANAGEMENT.TTe-INNOVATION_MANAGEMENT.R2DTech_Transfer)+
EXP(INNOVATION_MANAGEMENT.To_PubKnow)+
INNOVATION_MANAGEMENT.Spillover_Effect
DOCUMENT: Since "Patented A1 Rate" = LOGN(R2DTech Transfer and "Public Knowledge Rate" requires the non-
LOGN version of "PA1R," "R2DTech Transfer" is used instead in this equation.
: f INNOVATION_MANAGEMENT.Out_PubKnow =
INNOVATION_MANAGEMENT.Public_Know*INNOVATION_MANAGEMENT.PK_Dep
: f RESOURCE_MANAGEMENT.To_D_Infra =
(1-RESOURCE_MANAGEMENT.D_Income_Frac)*RESOURCE_MANAGEMENT.Out_Total_ResD
: f INNOVATION_MANAGEMENT.In_D_Infra = RESOURCE_MANAGEMENT.To_D_Infra
: f INNOVATION_MANAGEMENT.Out_D_Infra = INNOVATION_MANAGEMENT.D_Infra*INNOVATION_MANAGEMENT.R_Infra_Dep
: f INNOVATION_MANAGEMENT.Out_HS_Fund =
IF DEVELOPMENT.Successful_D > 0
THEN R&D_POLICY.HS_Inspect_Level
ELSE 0
: c INNOVATION_MANAGEMENT.HS_Effect5 =
IF NOT(INNOVATION_MANAGEMENT.Health_S_Fund>7000000) AND INNOVATION_MANAGEMENT.Health_S_Fund
> 6000000
THEN 0.05*INNOVATION_MANAGEMENT.HS_Prob_Change
ELSE 0
: c INNOVATION_MANAGEMENT.HS_Effect4 =
IF NOT(INNOVATION_MANAGEMENT.Health_S_Fund>8000000) AND INNOVATION_MANAGEMENT.Health_S_Fund
> 7000000
THEN 0.25*INNOVATION_MANAGEMENT.HS_Prob_Change
ELSE INNOVATION_MANAGEMENT.HS_Effect5
: c INNOVATION_MANAGEMENT.HS_Effect3 =

```

```

IF NOT (INNOVATION_MANAGEMENT.Health_S_Fund>9000000) AND INNOVATION_MANAGEMENT.Health_S_Fund
> 8000000
THEN INNOVATION_MANAGEMENT.HS_Prob_Change*0.5
ELSE INNOVATION_MANAGEMENT.HS_Effect4
: c INNOVATION_MANAGEMENT.HS_Effect2 =
IF NOT( INNOVATION_MANAGEMENT.Health_S_Fund>10000000 OR INNOVATION_MANAGEMENT.Health_S_Fund=0)
AND INNOVATION_MANAGEMENT.Health_S_Fund>9000000
THEN INNOVATION_MANAGEMENT.HS_Prob_Change*0.75
ELSE INNOVATION_MANAGEMENT.HS_Effect3
: c INNOVATION_MANAGEMENT.HS_Effect1 =
IF INNOVATION_MANAGEMENT.Health_S_Fund >10000000
THEN INNOVATION_MANAGEMENT.HS_Prob_Change
ELSE INNOVATION_MANAGEMENT.HS_Effect2
: c INNOVATION_MANAGEMENT.HS_Effect =
IF INNOVATION_MANAGEMENT.Health_S_Fund =0
THEN INNOVATION_MANAGEMENT.HS_Prob_Change*INNOVATION_MANAGEMENT.Health_S_Fund
ELSE INNOVATION_MANAGEMENT.HS_Effect1
: c INNOVATION_MANAGEMENT.If_HS_Change =
IF INNOVATION_MANAGEMENT.HS_Effect >0
THEN INNOVATION_MANAGEMENT.HS_Effect
ELSE 0
: f INNOVATION_MANAGEMENT.In_HS_Prob =
IF INNOVATION_MANAGEMENT.If_HS_Change > 0
THEN INNOVATION_MANAGEMENT.HS_Prob+INNOVATION_MANAGEMENT.If_HS_Change
ELSE INNOVATION_MANAGEMENT.HS_Prob-INNOVATION_MANAGEMENT.If_HS_No_Change
: f INNOVATION_MANAGEMENT.Out_HS_Prob = INNOVATION_MANAGEMENT.HS_Prob
: c RESOURCE_MANAGEMENT.Prop_RtoD =
IF RESOURCE_MANAGEMENT.Mobility_Cap = 1
THEN RESOURCE_MANAGEMENT.Out_RD%Mob
ELSE RESOURCE_MANAGEMENT.RtoD_Rate
: f RESOURCE_MANAGEMENT.In_R_Lab =
RESOURCE_MANAGEMENT.Biotech_Labor*RESOURCE_MANAGEMENT.Prop_RtoD
: f RESOURCE_MANAGEMENT.In_D_Lab =
RESOURCE_MANAGEMENT.Biotech_Labor*(1-RESOURCE_MANAGEMENT.Prop_RtoD)
: f INNOVATION_MANAGEMENT.In_Lic_R_Clt = INNOVATION_MANAGEMENT.In_LicR
: f INNOVATION_MANAGEMENT.In_Lic_D_Clt = INNOVATION_MANAGEMENT.In_LicD
: f DEVELOPMENT.Off_Market = CONVEYOR_OUTFLOW
: f RESOURCE_MANAGEMENT.In_Total_ResD =
RESOURCE_MANAGEMENT.PreTax_Kd-(RESOURCE_MANAGEMENT.PreTax_Kd*R&D_POLICY.Tax_Rate)
: f RESOURCE_MANAGEMENT.In_Govt_D =
RESOURCE_MANAGEMENT.Out_Res_Govt*((1-R&D_POLICY.R&D_Rate)-R&D_POLICY.Infra_Rate)
DOCUMENT: The net rate of investment the government allocates for development activities in biotech is so small
(1-R&D rate)-Infra rate, because it is assumed in the model that the vast majority of development activities take place
within the private sector, therefore not requiring governmental subsidy.

```

```

: f RESOURCE.MANAGEMENT.To_R.Lab = CONVEYOR OUTFLOW
: f RESOURCE.MANAGEMENT.To_D.Lab = CONVEYOR OUTFLOW
: c RESOURCE.MANAGEMENT.VCI1 =
IF RESOURCE.MANAGEMENT.VC.Total < 10000000 AND RESOURCE.MANAGEMENT.VC1= 2
THEN RESOURCE.MANAGEMENT.Out.Inlt.VC
ELSE 0
: c RESOURCE.MANAGEMENT.VCIR =
IF RESOURCE.MANAGEMENT.Intl.VC.Switch = 1
THEN RESOURCE.MANAGEMENT.VCI1
ELSE 0
: c RESOURCE.MANAGEMENT.VCI3 =
IF RESOURCE.MANAGEMENT.VC.Total<10000000 AND NOT(RESOURCE.MANAGEMENT.VC1 =2 OR RE-
SOURCE.MANAGEMENT.VC1=3) AND RESOURCE.MANAGEMENT.VC1 =4
THEN 0.5*RESOURCE.MANAGEMENT.Out.Inlt.VC
ELSE 0
: c RESOURCE.MANAGEMENT.VCI_Splt =
IF RESOURCE.MANAGEMENT.Intl.VC.Switch = 1
THEN RESOURCE.MANAGEMENT.VCI3
ELSE 0
: c RESOURCE.MANAGEMENT.SpltVCR =
IF NOT(RESOURCE.MANAGEMENT.VC1=2) AND RESOURCE.MANAGEMENT.VC1=4
THEN (0.5*RESOURCE.MANAGEMENT.Out.VC+RESOURCE.MANAGEMENT.VCI_Splt)
ELSE 0
: f RESOURCE.MANAGEMENT.In.VCtoR =
IF RESOURCE.MANAGEMENT.VC1 = 2
THEN (RESOURCE.MANAGEMENT.Out.VC+RESOURCE.MANAGEMENT.VCIR)
ELSE RESOURCE.MANAGEMENT.SpltVCR
: c RESOURCE.MANAGEMENT.VCI2 =
IF RESOURCE.MANAGEMENT.VC.Total < 10000000 AND RESOURCE.MANAGEMENT.VC1 = 3
THEN RESOURCE.MANAGEMENT.Out.Inlt.VC
ELSE 0
: c RESOURCE.MANAGEMENT.VCID =
IF RESOURCE.MANAGEMENT.Intl.VC.Switch = 1
THEN RESOURCE.MANAGEMENT.VCI2
ELSE 0
: c RESOURCE.MANAGEMENT.SpltVCD =
IF NOT(RESOURCE.MANAGEMENT.VC1=3) AND RESOURCE.MANAGEMENT.VC1=4
THEN (0.5*RESOURCE.MANAGEMENT.Out.VC+RESOURCE.MANAGEMENT.VCI_Splt)
ELSE 0
: f RESOURCE.MANAGEMENT.In.VCtoD =
IF RESOURCE.MANAGEMENT.VC1 = 3
THEN (RESOURCE.MANAGEMENT.Out.VC+RESOURCE.MANAGEMENT.VCID)
ELSE RESOURCE.MANAGEMENT.SpltVCD
: c INNOVATION.MANAGEMENT.Total_R&D.Infra =

```

INNOVATION_MANAGEMENT.D.Infra+INNOVATION_MANAGEMENT.R.Infra
TIME SPECS
STARTTIME=0
STOPTIME=25
DT=0.5
INTEGRATION=EULER
RUNMODE=NORMAL
PAUSEINTERVAL=INF

Software package: iSee Systems' STELLA v9.1.

BIBLIOGRAPHY

- Aghion, P., David, P.A., and Foray, D. (2009). *Science, technology and innovation for economic growth: Linking policy research and practice in [stig] systems*. *Research Policy*, vol. 38(4):pages 681–693.
- Aghion, P., Howitt, P., Brant-Collett, M., and García-Peñalosa, C. (1998). *Endogenous growth theory*. MIT Press., Cambridge, Mass.
- AMC (2010). *Biología en México*. Estudio producido por la Academia Mexicana de Ciencias. Estados Unidos Mexicanos.
- Arias, O.C. and Bolívar, Z.F. (2002). *Biología moderna para el desarrollo de México en el siglo XXI: Retos y oportunidades*. CONACyT, México.
- Arrow, K. (1959). *Economic welfare and the allocation of resources for invention*. In *The Rate and Direction of Inventive Activity: Economic and Social Factors*, NBER Chapters, pages 609–626. National Bureau of Economic Research, Inc.
- ASEBIO (2010). *Informe ASEBIO 2009*. Asociación Española de Bioempresas, ASEBIO, Madrid, Spain.
- Balzatz, M. (2006). *Economic analysis of innovation: Extending the concept of National Innovation Systems*. Edward Elgar Publishing Limited, Northampton, Mass.
- Barrell, R., Mason, G., and O'Mahony, M. (2000). *Productivity, innovation, and economic performance*. Cambridge University Press., Cambridge, England.
- BioCat (2009). *Report on the state of biotechnology, biomedicine, and medical technology in Catalonia*. The Bio Region of Catalonia, Barcelona, Spain.
- Bohrer, R.A. (2007). *A guide to biotechnology law and business*. Carolina Academic Press, Durham, NC.
- Bolívar, Z.F., Alarcón, S.D., Herrera Estrella, L., and (México), E.C.N. (2003). *Biología agrícola*. El Colegio Nacional., México.
- Bolívar, Z.F., CONACyT, iBT UNAM., Nacional., E.C., and (México), C. (2004). *Fundamentos y casos exitosos de la biología moderna: Recomendaciones para el desarrollo y consolidación de la biología en México*. Academia Mexicana de Ciencias., México.
- Burk, D.L. (2004). *Dna rules: legal and conceptual implications of biological "lock-out" systems*. *California Law Review*, vol. 92(6):pages 1553–1587.
- Caballero, R.J. and Jaffe, A.B. (1993). *How high are the giant's shoulders: An empirical assessment of knowledge spillovers and creative destruction in a model of economic growth*. *NBER Macroeconomics Annual*, vol. 8:pages 15–74.

- Canada (2011). *Trilateral arrangement; documentation requirements for lmos intended for direct use as food or feed, or for processing*. URL <http://www.bch.gc.ca/default.asp?lang=En&n=CD5215D7-1&xsl=bchdescriptor,showfull&xml=09A8799D-8196-40B0-9B68-DF7DAAFD4BBF>.
- Carlsson, B. and Jacobsson, S. (1997). *In search of useful public policies: Key lessons and issues for policy makers*. Kluwer Press.
- Casper, S. and Waarden, F. (2000). *Innovation and institutions: A multidisciplinary review of the study of innovation systems*. Edward Elgar, Cheltenham, UK.
- CDTI (2011). *Presentation*. URL <http://www.cdti.es/index.asp?MP=14&MS=59&MN=1>.
- Chang, Y.C. (2009). *Systems of innovation, spatial knowledge links and the firm's innovation performance: Towards a national-global complementarity view*. *Regional Studies*, vol. 49(9):pages 1199–1223.
- CIBIOGEM (2011). *¿qué es la cibio gem?* URL <http://www.cibio gem.gob.mx/Acerca/Paginas/default.aspx>.
- Cimoli, M. (2000). *Developing innovation systems: Mexico in a global context*. Continuum., London, UK.
- COFUPRO (2011). *"conócenos"*. URL <http://www.cofupro.org.mx/>.
- CONACyT (2011). *Dirección adjunta de desarrollo científico*. URL <http://www.conacyt.gob.mx/Cientifico/Paginas/Default.aspx>.
- DaSilva, E.J. (2004). *The colors of biotechnology: Science, development and humankind*. *Electronic Journal of Biotechnology*, vol. 7(3).
- Davis, D.D. (1986). *Managing technological innovation*. Jossey-Bass., San Francisco.
- Dibner, D.R., Lemer, A.C., and (U.S.), N.R.C. (1986). *The role of public agencies in fostering new technology and innovation in building*. National Academy Press., Washington, D.C.
- EC (2003). *Safe management of gmos: the cartagena protocol on biosafety becomes law*. IP/03/1236. EC IP.
- EC (2011a). *Seventh framework programme (fp7)*. URL http://cordis.europa.eu/fp7/home_en.html.
- EC (2011b). *Glossary to european integration and the institutions and activities of the eu*. URL http://europa.eu/legislation_summaries/glossary/.

- EC (2011c). *European commission legislation*. URL http://ec.europa.eu/legislation/index_en.htm.
- EC (2011d). *Gmos in a nutshell*. URL http://ec.europa.eu/food/food/biotechnology/gmo_nutshell_en.htm.
- EUM (2002). *Ley de ciencia y tecnología*. DOF 05-06-2002. Estados Unidos Mexicanos.
- EUM (2009a). *Decreto por el que se reforman, adicionan y derogan diversas disposiciones de la ley de ciencia y tecnología*. DOF 12-06-2009. Estados Unidos Mexicanos.
- EUM (2009b). *Ley de bioseguridad de organismos genéticamente modificados*. DOF 12-06-2009. Estados Unidos Mexicanos.
- EUM (2010a). *Ley de ciencia y tecnología*. DOF 27-04-2010. Estados Unidos Mexicanos.
- EUROPABIO (2007). *The yic status handbook for policy makers*. The European Association for Bioindustries, Brussels, Belgium. Full Booklet.
- Forrester, J.W. (1961). *Industrial dynamics*. M.I.T. Press., ACambridge, Mass.
- Freeman, C. and Soete, L. (1997). *The economics of industrial innovation*. Routledge Press., Oxford, UK.
- Freeman, S. and Polasky, S. (1992). *Knowledge-based growth*. *Journal of Monetary Economics*, vol. 30(1):pages 3–24.
- FSS (2011). *Normas internacionales y foráneos en biomedicina y biotecnología*. URL <http://sites.google.com/site/fsantaella/salud--medicamentos-y-servicios-sociales/biotecnologia/>.
- Gandolfo, G. (1972). *Mathematical methods and models in economic dynamics*. North-Holland Pub. Co., Amsterdam.
- Gandolfo, G. (1996). *Economic dynamics*. Springer., Berlin.
- Genóma España, F. (2009). *Relevancia de la biotecnología en España 2009*. Genóma España, Madrid, Spain.
- Gunnarsson, J. and Wallin, T. (2011). *An evolutionary approach to regional systems of innovation*. *Journal of Evolutionary Economics*, vol. 21(2):pages 321–340.
- Hertog, P., Reme, S., and OECD. (2001). *Innovative clusters: Drivers of national innovation systems*. OECD., Paris.

- Hung, S.C. (2000). *Institutions and systems of innovation: an empirical analysis of taiwan's personal computer competitiveness*. *Technology in Society*, vol. 22(2):pages 175–187.
- IMI (2011). *Research agenda*. URL <http://www.imi.europa.eu/content/research-agenda>.
- INEGI (2008). *Recursos humanos: Población que completó exitosamente el nivel de educación isced 5 o superior y está ocupada en actividades de ciencia y tecnología, por nivel de educación y campo de la ciencia según ocupación, 2008*. On line: <http://www.inegi.org.mx>. Estados Unidos Mexicanos.
- INEGI (2011). *Recursos humanos: Miembros del sistema nacional de investigadores según área de conocimiento, 1991-2010*. On line:<http://www.inegi.org.mx>. Estados Unidos Mexicanos.
- Jasanoff, S. (2005). *Designs on nature*. Princeton University Press, Princeton, NJ.
- Jones, C.I. and Romer, P.M. (2009). *The new kaldor facts: Ideas, institutions, population, and human capital*. *Working Paper*, (15094).
- Kamien, M.I. and Schwartz, N.L. (1982). *Market structure and innovation*. Cambridge University Press, Cambridge, UK.
- Kim, L. and Nelson, R.R. (2000). *Technology, learning and innovation: Experiences of newly industrializing economies*. Cambridge University Press., Cambridge, U.K.
- Kuhn, T.S. (1970). *The structure of scientific revolutions*. University of Chicago Press., Chicago.
- Legasto, A., Forrester, J.W., and Lyneis, J.M. (1980). *System dynamics*. North-Holland Pub. Co., Amsterdam.
- Loasby, B.J. (1999). *Knowledge, Institutions, and Evolution in Economics*. London, Routledge.
- López, R.E. and Piccaluga, A. (2000). *Knowledge flows in national systems of innovation: A comparative analysis of sociotechnical constituencies in Europe and Latin America*. E. Elgar Pub., Cheltenham, UK.
- Lucas, R.E. (1993). *Making a miracle*. *Econometrica*, vol. 61(2):pages 251–272.
- Lundvall, B.Å. (1985). *Product innovation and user-producer interaction*. *Industrial Development Research Series*, vol. 31. Aalborg, Aalborg University Press.
- Lundvall, B.Å. (1988). *Innovation as an interactive process: From user-producer interaction to the national system of innovation*. London, Pinter.

- Lundvall, B.Å. (1992). *National systems of innovation: Towards a theory of innovation and interactive learning*. London, Pinter.
- Lundvall, B.Å. (1998). *Why study national systems and national styles of innovation? Technology Analysis and Strategic Management*, vol. 10(4):page 407422.
- Lundvall, B.Å., Joseph, K. J., C.C., and Vang, J. (2009). *Handbook on innovation systems and developing countries: Building domestic capabilities in a global setting*. Edward Elgar Publishing Limited, Cheltenham, UK.
- Maier, F.H. (1998). *New product diffusion models in innovation management-a system dynamics perspective*. *System Dynamics Review*, vol. 14(4):pages 285–308.
- Malerba, F. (2004). *Sectoral systems of innovation: Concepts, issues and analyses of six major sectors in Europe*. Cambridge University Press., New York, N.Y.
- Malerba, F. (2005). *Sectoral systems of innovation: a framework for linking innovation to the knowledge base, structure and dynamics of sectors*. *Economics of Innovation and New Technology*, vol. 14:pages 63–82.
- Malmberg, A. and Krugman, P. (1996). *Review of development, geography, and economic theory*. *Geografiska Annaler. Series B. Human Geography*, vol. 78(2):pages 117–118.
- Mazzucato, M. and Dosi, G. (2006). *Knowledge accumulation and industry evolution: The case of pharma-biotech*. Cambridge University Press., Cambridge, UK.
- MICINN (2011a). *Ingenio 2010*. URL <http://www.micinn.es/portal/site/MICINN/menuitem.7eeac5cd345b4f34f09dfd1001432ea0/?vgnextoid=0714128e6f0b1210VgnVCM1000001a04140aRCRD>.
- MICINN (2011b). *Nueva ley de la ciencia, la tecnología y la innovación*. URL <http://www.micinn.es/portal/site/MICINN/menuitem.29451c2ac1391f1febebed1001432ea0/?vgnextoid=6ba4259e8e5f6210VgnVCM1000001d04140aRCRD>.
- Miller, V. and Clark, E. (2011). *The european union: A guide to terminology, procedures and sources*. Library, House of Commons. Full Booklet.
- Milling, P. (1996). *Modeling innovation processes for decision support and management simulation*. *System Dynamics Review*, vol. 12(3):pages 221–234.
- Milling, P. (2001). *An integrative view of R&D and innovation processes*, pages 509–514. Simulation Councils.
- Milling, P. and Maier, F. (1993). *Dynamic consequences of pricing strategies for research and development and the diffusion of innovations.*, pages 358–367. Cancun, Mexico: The System Dynamics Society.

- Milling, P. and Maier, F. (1996). *Invention, innovation und diffusion*. Duncker&Humblot, vol. 1.
- Milling, P. and Maier, F. (2001). *Dynamics of r&d and innovation diffusion*. *Proceedings of the International Conference on System Dynamics*.
- Nelson, R.R. (1993). *National innovation systems: A comparative analysis*. Oxford University Press., New York, NY.
- OECD (1995). *National systems for financing innovation*. OECD., Paris.
- OECD (1999). *Managing national innovation systems*. OECD., Paris.
- OECD (2001a). *Innovative networks: Co-operation in national innovation systems*. OECD., Paris.
- OECD (2005). *A framework for biotechnology statistics*. OECD., Paris.
- OECD (2006a). *Innovation in pharmaceutical biotechnology: Comparing national innovation systems at the sectoral level*. OECD., Paris.
- OECD (2008). *Knowledge markets in life sciences*. Issues paper for the OECD workshop on Knowledge markets in life sciences., Paris. Full paper.
- OED (2011). "*idea, n.*". URL <http://www.oed.com/view/Entry/90954?rskey=gtWFK9&result=1&isAdvanced=false>.
- Ott, L. and Longnecker, M. (2001). *An introduction to statistical methods and data analysis*. Duxbury., Australia.
- Peters, S. (2006). *National systems of innovation: Creating high-technology industries*. Palgrave Macmillan., Basingstoke, England.
- Pohlmann, M., Gebhardt, C., and Etzkowitz, H. (2005). *The development of innovation systems and the art of innovation management-strategy, control and the culture of innovation*. *Technology Analysis and Strategic Management*, vol. 17(1):pages 1–8.
- Polenske, K.R. (2007). *The economic geography of innovation*. Cambridge, UK, Cambridge University Press.
- Remøe, S., Guinet, J., and OECD (2002). *Dynamising national innovation systems*. OECD, Paris.
- Romer, P.M. (1990). *Endogenous technological change*. *Journal of Political Economy*, vol. 98(5):pages part 2: 71–102.
- Romer, P.M. (1994). *The origins of endogenous growth*. *The Journal of Economic Perspectives*, vol. 8(1):pages 3–22.

- Schmoch, U., Rammer, C., and Legler, H. (2006). *National systems of innovation in comparison: Structure and performance indicators for knowledge societies*. Springer., Dordrecht.
- Schröder, H.H. (1973). *Zum problem einer produktionsfunktion für forschung und entwicklung*. Meisenheim am Glam: Verlag Anton Hain, Germany.
- Segerstrom, P.S. (2007). *Intel economics*. *International Economic Review*, vol. 48(1):pages 247–280.
- Shone, R. (2001). *An introduction to economic dynamics*. Cambridge University Press., New York, NY.
- SNITT (2011). "*index*". URL <http://www.snitt.org.mx/index.html>.
- Solow, R.M. (2000). *Growth theory: An exposition*. Oxford University Press., New York, NY.
- Sugumaran, V. (2002). *Intelligent support systems: Knowledge management*. IRM Press., Hershey, PA.
- Tavares, A.T. and Teixeira, A. (2006). *Multinationals, clusters and innovation: Does public policy matter?* Palgrave Macmillan., Basingstoke, England.
- Uyarra, E. (2009). *What is evolutionary about 'regional systems of innovation'? implications for regional policy*. *Journal of Evolutionary Economics*, vol. 20(1):pages 115–137.
- van Beuzekom, B. and Arundel, A. (2009). *OECD Biotechnology Statistics 2009*. OCDE, Paris.