REVISITING THE TRADE COMPLEXITY AND ECONOMIC GROWTH NEXUS: DOES TRADE COMPOSITION MATTER?

A Thesis

Presented to the Faculty of the Graduate School

of Cornell University

in Partial Fulfillment of the Requirements for the degree of

Masters of Science

by

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August, 2009

ABSTRACT

Countries at all stages of economic development desire economic growth. Hausmann et al. (2007) devises a theoretical model and empirical analysis purporting that the type of goods which a country produces, categorized by the wealth level of all countries producing such goods, serves as one determinant of economic growth. Given the importance of this finding, particularly for developing countries, and the broad range of technical capabilities which countries possess, this study seeks to determine if this relationship holds within productive categories, classified by the technological requirements of their production, or simply represents a movement from primary and resource-based products to higher level manufactures. In particular, this study analyzes the sophistication of exports in five categories; primary products, resource based products, as well as low, medium, and high-tech manufactures, correlating each countries level of sophistication in these categories with economic growth using both five and ten year panels over the period 1962-2000. The empirical analysis confirms the importance of sophistication in the low-tech sector, which includes textiles and basic metal manufacturing, as an indicator of economic growth in all countries, while suggesting that sophistication within the high-tech sector, comprised of pharmaceuticals, electronics, and aircraft equipment, plays a significant role in highly developed countries.

BIOGRAPHICAL SKETCH

Brock Williams grew up on a grain farm in east-central Illinois. He attended the University of Illinois for his undergraduate studies majoring in economics with minors in international studies and classical civilizations. He received a B.S. degree with highest honors from the University of Illinois in 2007.

ACKNOWLEDGEMENTS

I would like to acknowledge the graduate faculty and staff of the department of Applied Economics and Management at Cornell University for their guidance and instruction over the past two years. It has been a joy working with and getting to know the members of this department. In addition, I would like to extend my most sincere appreciation to my committee members, Professors Nancy Chau and Hazem Daouk. Professor Daouk's econometric training both in and out of the classroom has been a critical component of my completion of this study and will doubtless continue to be of great help in the future. Meanwhile, Professor Chau's infectious enthusiasm for the study of international trade first attracted my interest in this topic and made the research process much more enjoyable. Clearly, I have greatly benefitted from her thoughtful evaluation of my work. Finally, I would like to thank my family, particularly my parents, for their unwavering belief in my ability and selfless support of my endeavors.

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CHAPTER 1

I. Introduction

In recent years a new literature has emerged, mostly from the work of Professors Rodrik and Hausmann at Harvard University as well as Professor Sanjaya Lall of Oxford University, which shifts the focus of growth studies away from endowments and institutions towards the composition of a country's productive sector and the spillover effects of that particular composition. Rodrik and Hausmann assert that particular "discovery costs" are associated with moving production into new sectors and that these costs must be borne by the entrepreneurs who forge the paths away from traditional production (Rodrik & Hausmann, 2003). However, once a country has moved its production away from non-traditional sectors, it lowers the resultant discovery costs into similar sectors. Given that discovery costs are prohibitive, in their model, a role exists for government policies that reduce these costs encouraging exploratory movements into new types of production, eventually leading a country onto the path of the most advantageous production composition.

In order to provide empirical analysis, Hausmann et al. (2007) appeal to the theories of comparative advantage in international trade using a country's weighted value-shares of exports as a determinant of productive sector composition. Though their model does not discuss exports directly, they assume that exports represent the most productive sectors of the economy, and thus serve as a proxy for overall productivity[1]. They create two variables PRODY, which associates each product with the GDP/capita of the countries that produce it, and EXPY, which totals the PRODY of each country's trade basket[2]. Thus, the EXPY variable represents not only the

[1] In addition, export data is easily accessible and available for over 100 countries from 1962-2000.
[2] These variables and their calculation are explained in more detail in the data section.

productive sector's composition, but also the relative sophistication (as proxied by income level) of that composition.

Though the EXPY variable is interesting in its own right (as later analysis will indicate) its greatest importance lies in its relation to economic growth, or GDP/capita increases over time. In order to determine this relationship Hausmann et al. (2007) regress economic growth on the EXPY variable and find a positive and significant relationship. In order to test the validity of these findings I have constructed my own PRODY and EXPY variables and will examine the relationship of these variables with GDP/capita growth over time. The authors' use of weighted value shares of trade as their proxy for the composition of the productive sector creates a distinct possibility that the EXPY variable has a different impact on countries with different export compositions.

II. Objective

The results from Hausmann et al. (2007) focus on the overall sophistication of a country's exports and its relation with growth. However, results from the original paper and my own analysis in Chapter 2 suggest that some countries such as Chile have low overall sophistication levels, but periods of high growth. Moreover, given Chile's export focus on primary and resource based products compared with other high growth countries such as the United States, the question arises as to whether this export sophistication factor affecting growth stems from the entire range or merely a subset of a country's production. The objective of this study is to revisit the results of Hausmann et al. (2007) and extend their work, examining the resilience of the impact of export sophistication on growth after disaggregating exports into sub-categories based on the technology involved in their production[3].

[3] The classification used in this paper was developed by Sanjaya Lall of Oxford University (Lall, 2000).

III. Literature Review of Trade Complexity and Growth

In addition to more specific economic aspirations all countries desire economic growth. Gross domestic product per capita denotes the value of goods and services produced per member of the population and thus serves as a widely used measure of economic well-being. Economic growth, defined in this paper as an annual increase in GDP per capita, reflects an improvement in a country's domestic production, providing the means for higher incomes, greater employment, and increased standards of living. Therefore, research on the relationship between economic growth and the productive sectors of the economy can provide policy makers with important information regarding those industries most likely to advance overall efficiency and stimulate economic growth.

However, two main policy approaches exist regarding the proper use of this information by governments. Lall (2004) describes the contrasting viewpoints of the neo-liberal and structuralist policy frameworks. Essentially neo-liberal policy, represented by the Washington Consensus, focuses on the ability of the market to reward successful industries and channel entrepreneurial capital and investment toward the most productive sectors of the economy, directing countries automatically toward those industries in which they can compete most efficiently within the world market. Hence, according to this view, governments simply need to establish the appropriate institutional framework, open their economies to world competition by relaxing international trade restrictions, and let the invisible hand guide resources towards their most efficient use. Meanwhile, the structuralist school suggests that governments play a more important role than simply maintaining macro-stability and supporting the rule of law. As Lall states, "the structuralist view puts less faith in free markets as the driver of dynamic competitiveness and more in the ability of governments to mount interventions effectively," (Lall, 2004). However, significant disagreement exists in the discussion as to which "interventions" are indeed most effective.

A primary motivation for this structuralist policy emerges from empirical evidence in developing country growth experience. Rodrik (2003) and Lall (2000) cite a number of examples in recent economic history, including South Korea, Taiwan, and the performance of Latin America before and after Import Substitution Industrialization, that suggest that governments may indeed have a role to play in shaping the productive landscape of their economies and that this particular conglomeration of industries may impact the overall economic performance of a country. In the case of Latin America, an over-zealous approach to industrial policy with little regard to overall efficiency during the import substitution industrialization era caused the creation of poorly run state owned manufacturing enterprises which, protected by high tariff barriers, became inefficient. Following the Latin American debt crisis, the ensuing dependency of Latin American governments on funds from international organizations came with strict requirements to adhere to the neo-liberal policies on economic growth. However, as Rodrik and Hausmann (2003) mention, "Economic growth in the 1990s has been on average much lower than in the decades before 1980, even though the region was closed to trade and had poorer institutions by most benchmarks in the earlier period." The authors contrast this unsuccessful restructuring of policies with the experience of the export-led growth of the Asian economies of South Korea and Taiwan, noting that the latter's protective trade regimes and export subsidies managed to reward efficient industries leading to a competitive export sector and brought great success in economic growth though accompanied by policies unaccepted by the neo-classical approach.

The underpinnings of the neo-classical approach, meanwhile relate to the traditional Heckscher-Ohlin trade theory which suggests that a country will specialize in producing the things that require as inputs the factors of production in which it has an abundant natural endowment; labor or capital, in a simple two-factor model. A country can then trade what it produces with partners who have a different endowment, thus providing Ricardo's benefits of comparative advantage, though in terms of factor endowments rather than productive technologies, to all trading partners. Any change then in the composition of production, a shift from agriculture to manufacturing for instance, results entirely from changes in the underlying factors of production caused by development, an accumulation of capital in the example of the shift from agriculture to manufacturing.

However, this new body of literature, more in line with the structuralist policy framework, suggests that some additional learning must take place in order for a country to exploit fully its natural advantages. For instance, Lall (2000) criticizes the Heckscher-Olin model in favor of what he calls the capability approach suggesting that "comparative advantage depends more on the national ability to master and use technologies than on factor endowments in the usual sense." Hence, he attributes the need for this new approach to the fact that current trade theories focus too heavily on the "capacity" rather than the "capability", soft skills like management expertise, needed to shift production into new sectors (Lall, 2000). Essentially he asserts that structural transformations into new areas of production requires more than simply a change in factor endowments, but rather that efficiency in new sectors stems from having developed the skills needed to implement new technologies. If one can consider the temporary efficiency losses from this capability skill-set deficit as an adjustment cost for moving into new sectors, then Krugman (1991) derives a theoretical model that supports Lall's argument. Krugman (1991) finds that in the face of high adjustment costs, the historical structure of an economy ultimately determines its industrial sectors.

One also finds support for this proposition in economic history, for example in the case of Korea, which we discussed earlier with regard to its success in developing several high technology industrial sectors. Korea's ability to develop these industries did not simply stem from its capacity to import foreign technologies; "it is a striking fact that formal purchase of technology in complete packages through such means as turnkey plant contracts and licensing…accounts for only a modest share of the technology that has been mastered in Korea" (Evenson & Westphal, 1995). Evenson and Westphal (1995), precursors to Lall's strain of argument, highlight three necessary components for maximum efficiency in new industries; competent labor trained in similar industries, experimentation in particular adaptations of technology to local conditions, and an understanding of the most efficient combinations of available technologies. These characteristics then reflect a country's "capability" in becoming competitive in new industries and obviously require considerable learning. Rodrik and his co-authors take this argument one step further, discussing the causality between shifts in production composition and economic growth, suggesting that encouraging the development of these soft skills necessary for a structural shift in fact *causes* economic growth by providing the "capability" for expansion in a range of new activities (Rodrik & Hausmann, 2003).

One explanation of this causal link comes more from empirics than theory. Contrary to Ricardo's ideas of comparative advantage and specialization, Imbs and Wacziarg (2003) present empirical findings of a U-shaped relationship between sector concentration and economic development, suggesting that poor countries first diversify their productive capacities before specializing in areas of greatest advantage Moreover, the turn from diversification to specialization occurs quite late in the development process, suggesting that until countries are relatively wealthy they expand their production into new sectors rather than specialize. Rodrik (2008), in his book chapter on industrial policy sums up these findings suggesting that “the first order of business in development is to learn how to do new things, not to focus on what one already does well.”

Additional empirical evidence exists regarding the importance of expanding one’s export basket. Hummel and Klenow (2005) also find that while larger countries, in terms of population, produce a wider variety of exports, for richer countries this increase lies more in the extensive margin than intensive margin. Hence wealthier countries produce exports in a wider array of industries than their poorer counterparts. In addition, a recent paper by Saviotti and Frenken (2008) finds there to be an immediate correlation between increasing export variety in related products and economic growth. Meanwhile, they find the same relationship examining increased export variety in different sectors, but only after a time lag, suggesting that recouping the investment of a shift in production processes may take time. These empirical findings emphasize that a benefit exists for diversifying ones productive sectors.

Rodrik and Hausmann (2003) call this process of diversification in the early stages of development, a period of “economic self discovery.” This process of economic self-discovery requires forging into new sectors of production, ignoring the traditional areas of comparative advantage, seemingly defying the previously held theories of specialization and comparative advantage. However, the authors of this body of literature avoid departing from these theoretical foundations of international economics, rather they augment the economic theory with the case of market failures, in this case, the failure of the market to adequately encourage exploration for new areas of comparative advantage. This market failure occurs because the societal benefits of exploratory entrepreneurship, discovering the productive sectors in which the economy has a competitive advantage, exceed the private benefits. Hence, the economic returns from entry into the new sectors fail to provide an adequate incentive for exploration, particularly in developing countries, where, with less stringent intellectual property rights, competitors quickly erode profits in the new sector by emulating the first to arrive. Through this model of cost discovery and the market failure that ensues, Hausmann and Rodrik (2003) develop a framework that links increased export diversification with economic growth and hence provides a policy justification for encouraging production in new sectors.

However, later work by the same authors suggests that countries should focus not just on diversification, but rather diversification into products most likely to lead to future growth. Both Hausmann et al. (2007) and Lall (2005) develop a sophistication index which they use to rank products by the wealth level of the countries that export them[4]. According to Lall (2005), these product rankings then reflect the unique skills and capabilities possessed by richer countries; the "characteristics that allow high wage producers to compete in world markets." Though several of these characteristics cannot be imitated such as location of natural resources and proximity to large markets, countries can work to increase their technological aptitude. Lall (2005) describes this as "the ability to handle technologies efficiently (production capabilities) and improve them over time (minor innovation), realize scale and agglomeration economies, and organize suppliers efficiently." Hence, encouraging the production of higher ranked goods should lead countries to develop the skills which their production embodies and can be easily transferred to new technologies. Hausmann et al. (2007) take a slightly different approach in their use of

[4] This recent work by Lall and Hausmann et al. (2007) draws heavily from an earlier body of literature on technology spillovers and learning by doing. Stokey (1988) develops a theoretical model for one economy in which learning by doing in the production of succeedingly higher quality products plays a crucial role in growth. Young (1991) and Matsuyama (1992) consider an international trade model between developed and developing countries and find a motivation for trade protection in developing countries in order to ensure the production of higher quality goods and consequently, the benefits of "learning by doing." However, their models provide no measure of product quality and thus no method of empirically testing the relationship between product quality and growth.

the sophistication index, relating more to their original framework of cost discovery. They assume that more sophisticated products must reflect more productive technology and hence a country's adoption of these products increases its entrepreneurs' incentives to search for yet more efficient technologies leading to an increase in overall productivity and growth.

Hausmann together with other co-authors provides yet another avenue from which to address this issue of path-dependent productivity growth (Hidalgo et al. 2007). Through an extension to the varieties and quality ladders models the authors construct a measure they call product proximity, the probability that a country with a revealed comparative advantage in one good also has a revealed comparative advantage in another good. Similar to Lall's capability discussion, they assume that the efficient production of one good inevitably requires particular natural endowments, infrastructure, support industry networks, institutions, and human expertise that may be readily applied to the production of similar goods. Hence, once a country has developed the framework necessary to be competitive in one industry, it has already gained a significant advantage in moving into related industries. Using their product proximity measure, the authors construct a product space displaying the likelihood of moving within products as the geographic distance between them. The resulting network of industry clusters suggests that, as one might expect, higher level manufacturing industries such as automobiles and electronics have a number of branches connecting them to other lucrative industries. Thus, their analysis pinpoints another justification for encouraging the development of particular industries; in this case, those from which most other industries may easily be reached.

These various approaches to the debate on industrial policy and economic growth suggest there exist a number of factors, including both empirical evidence and theoretical propositions, which suggest that a country's particular industrial composition plays an important role in it's a ability to grow over time. Though previous experiences with industrial policy have had their drawbacks, the current literature seems to condone at least some level of policy intervention to channel investment into new and more productive sectors. While this paper follows the empirical approach of Hausmann et al. (2007) in measuring the sophistication of a country's exports, it draws on this entire body of literature for its motivation in examining the impact of trade composition on future economic growth.

The rest of this thesis is organized in three chapters. In Chapter 2 we revisit the empirical work of Hausmann et al. (2007) motivating the need for further investigation as to how this relationship between export sophistication and growth varies among different product categories. Chapter 3 provides further analysis, disaggregating the EXPYA variable into sectors by technology level, looking for trends among these sector sophistication scores over time, and examining their relationship with growth. Finally, we conclude our work with some final comments regarding this study in Chapter 4. Overall, we find that only sophistication in the low-tech category appears to be a robustly significant determinant of economic growth in a wide range of countries, suggesting that Hausmann et al.'s (2007) results may pertain to only a subset of industrial sectors, and may be dependent on a country's current level of development.

CHAPTER II

I. Introduction

As opposed to the assumption that economic efficiency increases and growth stem from the adoption of new technologies, endogenous growth models suggest that spillover effects from learning how to produce higher quality goods may be a driver of growth. Work by Stokey (1988), Young (1991), and Matsuyama (1992), provide theoretical models that support this view, but no empirical analysis. In the 2007 paper, “What you export matters,” Hausmann et al. develop a model of a similar nature to the previous endogenous growth literature, however, using exports as a proxy for the overall industrial structure they present a measure of product quality that allows for empirical testing. In their analysis they find export sophistication to be a robust determinant of economic growth. However, their study does not address whether this sophistication/growth relationship occurs within product categories or simply reflects a movement from agricultural and primary product production to higher level manufacturing.

This chapter examines Hausmann et al.’s (2007) index and verifies their original panel growth regressions using a broader set of observations. The objective of the chapter is to investigate the construction of the EXPY and PRODY variables, measures of a country’s export sophistication and a good’s product sophistication. Though Lall (2005) constructs a similar methodology to ascertain export sophistication, current literature makes use of the Hausmann et al. (2007) index, so this paper focuses on their specific construction. In addition, we seek to examine export sophistication in countries with a focus on primary and resource-based goods. Given that developing countries are most in need of strategies for improving economic growth and the importance that agriculture and primary products play in the export baskets of most developing countries, more information regarding the relationship between export sophistication and agricultural and primary product producers would be most interesting.

Our results present similar conclusions with the previous literature regarding the relationship between export sophistication and growth. We find export sophistication in both five and ten-year panels from 1962 – 2000 to be a robust and significant determinant of economic growth. In both pooled and panel regressions our results reiterate the previous findings suggesting that indeed the kinds of products a country exports do have some influence on its overall growth potential. However, we find that some fast growing primary and resource product exporters have very low sophistication scores, leading us to question if sophistication within product categories is reflected in this index, and if that type of sophistication is also a determinant of economic growth. These questions, which this aggregated measure of export sophistication fails to address, provide the motivation for our analysis in Chapter 3.

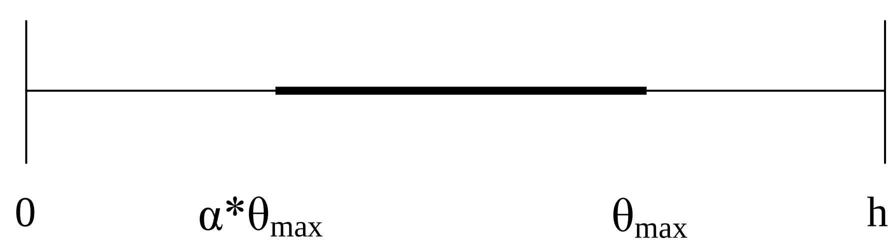


Figure 2.1 – The product space; Source: Hausmann et al. (2007)

II. θ_{Max} and the Product Space

Essentially, Hausmann et al. (2007) consider a production space represented in Figure 2.1 above. In this production space an investor chooses between investing in the traditional sector or in the modern sector. The productivity of investments in the modern sector, θ, ranges from 0 to *h*, where *h* represents an index of human capital, such that the maximum productivity of an investment is only constrained by the maximum level of human capital in the economy, one could consider this the maximum capability in the economy according to Lall's approach. Furthermore, imposing the previously mentioned framework of cost discovery, some θ_{max} exists, which represents the highest level of productivity currently discovered in the economy and only increases as more entrepreneurs invest in new projects discovering the productivity of new sectors. Meanwhile, information spillovers allow for the dissemination of the particular location of θ_{max}, such that subsequent entrants in the modern sector know that, subject to some discount factor for late entry, α, they will be able to achieve the productivity of θ_{max} producing at productivity level $\alpha*\theta_{max}$. Hence, information spillovers provide an economy of scale such that, any increase in θ_{max} leads to increases in $\alpha*\theta_{max}$ which in turn increases the expected profits of these entrepreneurs, who know that after risking an investment in a new sector, if their investment proves less productive than $\alpha*\theta_{max,}$ they can always emulate the other investors in the second period abandoning their own sector. Thus, any increase in θ_{max} necessarily causes an increase in productivity and hence economic growth[5].

[5] This entire theoretical framework follows directly from Hausmann et al. (2007), "What you export matters," the contribution of this paper lies in the deconstruction of their sophistication index by sector.

III. Construction of EXPY Variable/Data

According to this theoretical framework, given some measure of θ_{max}, or the productivity level of the economy, empirical analysis should suggest that rises in θ_{max} are correlated with increases in growth. Thus, completing the empirical analysis requires some measure of economy-wide productivity. Using the method of Hausmann et al. (2007) we consider a country's export basket as a fair representation of their overall productivity, assuming that a country exports only those goods in which it has the highest levels of productivity, and we correlate a particular level of sophistication to that trade basket by associating each product in it with the per capita GDP of the countries that produce it. The data for the analysis comes from the World Trade Flows dataset of imports and exports generated by Feenstra et al. (2005) and supported by the National Bureau of Economic Research, which covers 1962-2000, and the Penn World Tables created by Heston et al. (2002), which provide per capita GDP over the same period.

Country *k*'s export basket *X*, is comprised of *i* goods, such that the total export basket is equivalent to equation (2.1). Then x_{ki}/X_k represents the value share of each commodity *i*, where *i* refers to the 4-digit commodity code used in the World Trade Flows dataset. Thus, $PRODY_i$ associates the weighted value share of each commodity in a country's trade basket with that country's per capita GDP, see equation (2.2). The value share of each commodity is divided by the total value share of all other countries that produce this product, thereby if product *i* represents lower value shares in other countries, then country *k*'s per capita GDP is weighted heavier in the construction of $PRODY_i$.[6] Finally, we construct country *k*'s level of complexity by summing the

[6] This weighting by revealed comparative advantage distinguishes Hausmann et al.'s (2007) trade complexity variable from previous models.

PRODY levels over all *i* goods, which the country produces, weighted by its value share for that particular product, see equation (2.3)[7].

(2.1) $$X_k = \sum_i x_{ik}$$

(2.2) $$PRODY_i = \sum_k \frac{\frac{x_{ki}}{X_k}}{\sum_k \frac{x_{ki}}{X_k}} * GPD_k$$

(2.3) $$EXPY_k = \sum_i \frac{x_{ki}}{X_k} * PRODY_i$$

Thus, constructing these variables for each year is fairly straightforward. However, when examining product sophistication over our entire 39-year panel, a number of possible methods of construction present themselves. In this study we analyze three different measures of product sophistication over time. The most obvious allows the PRODY product sophistication measure to vary each year simply creating a variable following the method described above. However, one might also assume that while the sophistication index of products should be allowed to vary overtime there perhaps exists value in maintaining some consistency of such rankings. One could argue that forcing our index to have this memory would be crucial if we suppose that each year's sophistication index reflects more the current stage of development across all countries, rather than a wholly revamped technology structure. In order to incorporate this sophistication memory we also construct a PRODY index averaged over five-year intervals and a PRODY index that reports the average sophistication indices over the entire range of observations. In addition, given

[7] It may be noted that by construction per capita GDP is related to EXPY, and since both variables are used to explain growth, particular attention is paid to the issue of multi-collinearity. However, the VIF for both variables shows no cause for concern.

somewhat disconcerting rankings in the sophistication levels of countries during the 1970's (high oil prices caused oil rich countries to appear as the most sophisticated exporters), we have also constructed an index which does not include this time period. The estimation portion examines our regression results using each of these different indices.

In addition to these various PRODY constructions, there also exists a methodological issue in determining which countries to include in the overall construction of our sophistication variables. Hausmann et al. (2007) stress in their paper the possible bias that might appear in the production index if countries are included in its construction only in a limited number of years. Due to the particular method of constructing PRODY and the fact that most countries for which data does not exist over the entire period belong to the developing country category and hence will have lower GDP/capita, including these countries in some but not all years will introduce a degree of bias into the sophistication measure. Table A.1 in Appendix A lists all countries that have some missing observations and the number of years for which the data is available. Though including these countries in some but not all years, will undoubtedly impact the final sophistication index, because they are mostly developing countries, including them also provides a much richer understanding of the sophistication process, and hence we proceed with our analysis using all countries and years for which data exists. However, final results excluding these countries have been calculated and we present them in the final chapter for comparison.

The importance of measuring the complexity of trade and the relative simplicity of constructing the variables used by Hausmann et al. (2007) lend these measures to a multitude of analysis, some with significant policy implications. Rodrik has cited these variables in a series of his papers, and particularly notes their importance for China in his recent publication, "What's so special about China's exports”. He asserts that China’s growth stems from its production of highly sophisticated products, and thus its EXPY variable is much higher than those of country’s with similar or higher per capita GDP levels, for example several Latin American countries. Indeed, other economists have apparently found validity in these statistics as their use as a measure of the complexity of trade has moved beyond the growth literature. Recently, Gaofeng Han and Bin Xu use the PRODY of textile exports from China to measure the effect of the multi-fiber agreement on the complexity of traded textiles.

However, some dissidents argue that these indices have limitations. Masanaga Kumakura (2007) purports some mathematical inconsistencies with the measure beyond the scope of our current analysis and suggests, as I believe Hausmann et al. (2007) would also admit, that the EXPY variable provides no measure of discounting a country if its quest for heightened complexity causes it to transform structurally beyond its most productive levels, hence causing inefficient deployment of resources. For example, returning to our discussion of Import Substitution Industrialization, in the height of ISI Latin American countries perhaps forced their complexity beyond their most productive levels. However, regarding EXPY, no maximum based on relative productivity exists, in effect, the higher the better. Noting these possible inadequacies, EXPY remains the most accepted measure of complexity to date, so we proceed with our analysis. However, our addition to this index, deconstructing it into industrial sectors and examining its relation to growth, which we discuss in Chapter 3, provides an attempt to address this issue of ascertaining to what EXPY level a country should strive. We do this through growth regressions by income groups and find that indeed, the most beneficial level of EXPY may vary based on a country’s current level of development.

IV. Model and Empirical Analysis

The theoretical model developed by Hausmann et al. (2007) considers growth, or percentage change in per capita GDP, as some function of human capital, hc, and the discovered level of productivity, θ_{max} [8]. Though not explicitly developed in this particular theoretical model, it seems reasonable to assert that because we consider percentage changes in growth, the base from which we derive that percentage change likely plays some role in its determination (e.g. larger economies must undergo significant increases in production to achieve large percentage growth). Thus, we include initial per capita GDP in our growth function.

$$(2.4) \quad Growth = f(hc, \theta_{max,} GDP_0)$$

Assuming a linear relationship and taking the logarithm of the dependent variables we arrive at our simple regression model, where Y represents percentage change in per capita GDP.

$$(2.5) \quad Y = \alpha + \beta_1 \log(\theta_{max}) + \beta_2 \log(hc) + \beta_3 \log(GDP_0)$$

For our particular model we define human capital as the average years of schooling for everyone in the population above 15[9]. The source for our human capital measure comes from Barro and Lee's 2000 study on educational attainment. Meanwhile, we will use our constructed variable EXPY to represent θ_{max} because we assume that a more sophisticated compilation of exports represents an economy's push

[8] All per capita GDP figures used are in constant prices.

[9] Data is also available for human capital above age 25. We present results using both data sets, however, given little difference between the results and the greater number of observations available for the HC15 variable, our final regressions present only the results from this HC15 variable.

toward more "cost discovery" and thus higher productivity. Again per capita GDP figures come from the Penn World Tables. Our theoretical model suggests that increases in both EXPY and human capital should increase our annual percentage growth, while increases in initial per capita GDP likely cause percentage growth to decrease.

In their econometric analysis, Hausmann et al. (2007), include time dummies in each of their growth regressions. This makes sense considering the great number of external factors affecting overall GDP growth in any given year, particularly global bust and boom cycles. Moreover, an F-test confirms their pertinence so we include them in our analysis. Additional tests, including a goodness of fit test using adjusted R squared and Bayesian and Akaike Information Criteria for the possible inclusion of quadratic terms for human capital and EXPY as well as interactions among human capital, GDP/capita, and our sophistication variables suggested that these were unnecessary modifications. The details of these tests can be found in Appendix C. See below the final model for estimation, where δ represents the coefficient on the time dummy, d represents the dummy variable for each period, and a dummy for the first period has been excluded to avoid multi-collinearity or a "dummy trap". Thus, the constant term can be interpreted as the specific slope for the first period with each respective δ adjusting the slopes of later periods.

$$Y = \alpha + \beta_1 \log(\theta_{max}) + \beta_2 \log(hc) + \beta_3 \log(GDP_0) + \delta_2 d_2 (1965) + \delta_3 d_3 (1970) + \delta_4 d_4 (1975) + \delta_5 d_5 (1980) + \delta_6 d_6 (1985) + \delta_7 d_7 (1985) + \delta_8 d_8 (1990) + \delta_9 d_9 (1995) + \delta_9 d_9 (2000) \quad (2.6)$$

The compiled dataset considers per capita GDP growth over five and ten year intervals from 1962-2000. Thus, the data includes panels with nine and five separate periods of per capita GDP growth for 110 different countries, which when combined with available human capital data and our constructed EXPY variable yields 858 complete observations[10]. Tables 1 and 2 below report the summary statistics of our variables used in the regression analysis. Unfortunately, our dataset is not balanced such that we do not have all 9 observations for each country. The limited data on human capital greatly restricts our usable observations. Estimation includes pooled OLS as well as fixed and random effects from panel regressions. However, our tests and corrections for violations of classical assumptions focus on the pooled model.

Table 2.1 - Summary Statistics, 5-year panels

Variables	Observations	Mean	Std. Dev.	Min	Max
expya	1150	6458.385	2670.559	1881.666	12809.03
gdpg5a	1150	.0205624	.0440044	-.27722	.519675
gdpc	1150	7285.319	8206.361	170.55	67188.32
HC15	858	5.101235	2.851997	.12	12.05
HC25	782	4.881816	2.959061	.04	12.25

Table 2.2 - Summary statistics, 10-year panels

Variables	Observations	Mean	Std. Dev.	Min	Max
expya	640	6510.377	2664.482	1881.666	12809.03
gdpg10a	640	.0203096	.0331785	-.1508	.2449556
gdpc	640	7432.422	8489.345	359.15	66762.66
HC15	477	5.142201	2.887093	.12	12.05
HC25	401	5.044489	3.004123	.04	12.25

Tests for violation of the OLS assumptions of multi-collinearity, normality, heteroskedasticity, and autocorrelation revealed heteroskedasticity to be our only violation. Thus, we have reported our White's robust standard errors in all estimations,

[10] Our inclusion of 106 countries differs this study from the original work by Hausmann et al. (2007) which considers only 97 countries and 604 observations.

giving us inefficient but consistent estimators. Due to our time component in the panel regressions, we also consider the possible case of non-stationarity, which would cause inconsistency in our estimators and result in a spurious regression. Though we might expect per capita GDP to consistently drift upwards over time, our cross-sectional data provides enough variation that we have stationary data in all dependent and independent variables. See Appendix C for the details of these tests.

V. Estimation

The estimation of our model has been completed using Stata version 9.1. Table 2.3 shows the pooled model regression results using 110 countries and all 858 complete observations[11]. The signs on our variables reflect economic intuition for the most part. Given our logarithmic transformation of the dependent variables we can interpret unit changes (percentage points since we measure growth) in per capita GDP growth in terms of percentage changes in our dependent variables. Therefore, we find that a 10% increase in human capital, raising the average years of schooling of the above 15 population, enhances growth by about one-tenth of a percentage point in the pooled model. However, in the fixed-effects model, we find a negative, though insignificant, effect on human capital, which runs counter to economic intuition. However, this variable appeared very sensitive in the original regressions on trade and complexity in Hausmann et al. (2007) as well[12]. Meanwhile, higher initial per capita GDP results in lower growth over the period. However, our constructed variable EXPYA provides the most interesting results, suggesting that a 10% increase in EXPYA increases growth by .10 to .19 percentage points depending on whether we

[11] Tables A.1, A.2 in the appendix list the countries, with and without full sets of observations, used in this study.
[12] The next section investigates the use of different panel regression methods and further discusses this human capital perplexity.

consider an overall cross-country pooled regression or a fixed-effects regression that allows for different effects within each country group. Thus, we have empirically proven our theoretical assumption that increasing the complexity of one's trade, and hence boosting the "discovered" productivity level θ_{max} does indeed increase growth.

Table 2.3 – Export sophistication and growth, pooled and fixed-effects models

	(1) Pooled-5	(2) FE-5	(3) Pooled-10	(4) FE-10
VARIABLES	gdpg5a	gdpg5a	gdpg10a	gdpg10a
lnexpya	0.0188***	0.0158**	0.0151***	0.0107
	(0.00686)	(0.00759)	(0.00505)	(0.00689)
lnhc15	0.0115***	-0.00667	0.00975***	-0.0107*
	(0.00248)	(0.00545)	(0.00249)	(0.00605)
lngdpc	-0.00889**	-0.0282***	-0.00676***	-0.0230***
	(0.00357)	(0.00914)	(0.00259)	(0.00472)
Constant	-0.0630*	0.133*	-0.0501	0.135*
	(0.0374)	(0.0794)	(0.0316)	(0.0724)
Observations	858	858	477	477
R-squared	0.152	0.164	0.173	0.229
Countries		110		109

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Overall, our data shows very similar results to those available in the published literature. We see that our export sophistication variable appears significant above the 5% level in each model specification except equation (4). The impact of this product sophistication ranges from 0.0107 to 0.0188 suggesting that a 10% increase in product sophistication correlates to above one-tenth of a percentage point increase in GDP/capita growth. Further evidence from panel regressions using only countries with consistent observations throughout the panel reports a growth impact near three-tenths of one percentage, suggesting that the estimates above may be conservative, see Table A.3 in the appendix.

VI. Robustness and variable construction selection

A number of options exist regarding the choice of the appropriate base model for our inference on the effects of sophistication on economic growth. As discussed in Section III, we have constructed four different export sophistication variables, each based on a slightly different product sophistication ranking. In addition, we have some choice as to our measure of a country's level of human capital as well as its five and ten-year rates of economic growth. Finally, though the structure of our dataset lends itself to panel form regression analysis, it requires some consideration to determine which method of analysis most accurately reflects the patterns between economic growth and export sophistication found in our data. Each of these various variables and configurations of our estimation have economic merit and deserve thoughtful selection. Hence, in this section we discern the best variables and regression techniques for use in our model among these various possibilities and consider the estimations from these various specifications as a robustness test for our underlying framework.

Revisiting our previous discussion regarding the various methods of constructing the PRODY product sophistication index, we can analyze the results in Table 2.4 with respect to each of our different indices. EXPYA takes the average of the PRODY indices over the entire period, while EXPY allows the product sophistication to vary each year, and EXPY5A reflects a five-year moving average of the PRODY values. Finally, EXPYNOILA, represents an average product sophistication level excluding the period 1970-1981 during which oil producing countries appear as the most sophisticated exporters, perhaps skewing our results. Most importantly we note that all estimations maintain the significance of the EXPY measure and maintain the same sign and a similar magnitude. In addition, the use of the various indices does not appear to change the sign, significance, or magnitude of any covariates. Hence, we defer to the previous literature which uses the overall average of product sophistication over the entire period (EXPYA) and follow suit in the remainder of this chapter and the next.

Table 2.4 – Export sophistication and growth, PRODY index comparison

	(1) Pooled-5	(2) Pooled-5	(3) Pooled-5	(4) Pooled-5
VARIABLES	gdpg5a	gdpg5a	gdpg5a	gdpg5a
lnexpya	0.0188***			
	(0.00686)			
lnhc15	0.0115***	0.0115***	0.0111***	0.00550**
	(0.00248)	(0.00258)	(0.00257)	(0.00249)
lngdpc	-0.00889**	-0.00762**	-0.00866**	-0.00651***
	(0.00357)	(0.00357)	(0.00356)	(0.00210)
lnexpy		0.0129**		
		(0.00639)		
lnexpy5a			0.0166**	
			(0.00646)	
lnexpynoila				0.0160***
				(0.00463)
Constant	-0.0630*	-0.0149	-0.0360	-0.0719**
	(0.0374)	(0.0307)	(0.0313)	(0.0313)
Observations	858	858	858	858
R-squared	0.152	0.144	0.150	0.028

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In addition to examining these different sophistication measures, we have also considered possible variations in the measure of growth and the particular human capital variables used in our analysis. Table 2.5 below compares the original regression, reporting five-year growth as the average of growth for each of the five years and using human capital as the average years of schooling for the population over 15, with variations to these specifications. The second regression defines growth as the change in GDP/capita from the first year of each period to the fifth year with no consideration for variation within the period. The third regression replaces human capital above age 15 with an education measure for the population above 25, decreasing the observations from 858 to 782. Again, in both variations of our original equation we see no change in significance or sign and no major adjustment in magnitudes. However, using the overall five-year growth equation, we see a much higher impact from EXPYA, our country sophistication variable. This most likely reflects a smoothing of short periods of economic decline which may have existed within the five-year periods. Given the similarity in results we have chosen to focus our proceeding analysis on only the more detailed results, which includes the greater number of observations.

Table 2.5 – Export sophistication and growth, human capital/growth comparison

	(1) Pooled-5	(2) Pooled-5	(3) Pooled-5
VARIABLES	gdpg5a	gdpg5	gdpg5a
lnexpya	0.0188***	0.0260***	0.0198***
	(0.00686)	(0.00733)	(0.00768)
lnhc15	0.0115***	0.0150***	
	(0.00248)	(0.00290)	
lngdpc	-0.00889**	-0.0143***	-0.00926**
	(0.00357)	(0.00432)	(0.00403)
lnhc25			0.0109***
			(0.00240)
Constant	-0.0630*	-0.0850**	-0.0701*
	(0.0374)	(0.0376)	(0.0416)
Observations	858	857	782
R-squared	0.152	0.136	0.144

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2.6 – Export sophistication and growth, five/ten year panel regressions

	(1) RE-5	(2) FE-5	(3) RE-10	(4) FE-10
VARIABLES	gdpg5a	gdpg5a	gdpg10a	gdpg10a
lnexpya	0.0265***	0.0158**	0.0160***	0.0107
	(0.00756)	(0.00758)	(0.00516)	(0.00689)
lnhc15	0.0152***	-0.00667	0.00865***	-0.0107*
	(0.00302)	(0.00545)	(0.00290)	(0.00605)
lngdpc	-0.0148***	-0.0281***	-0.00713***	-0.0230***
	(0.00451)	(0.00914)	(0.00272)	(0.00472)
Constant	-0.0852**	0.1329*	-0.0545	0.135*
	(0.0386)	(0.0794)	(0.0344)	(0.0724)
Observations	858	858	477	477
Countries	110	110	109	109

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Next we consider different panel models with which to analyze our data. Table 2.6 above displays both fixed and random-effects regressions for our five and ten-year panels. The fixed-effects estimation for our model effectively includes dummy variables for each country in the dataset. This allows for individual country variability, such that the coefficient on EXPYA now explains the effect of complexity on growth net of effects specific to certain countries. Again, following our earlier finding of heteroskedasticity we report White's robust standard errors. Allowing for these fixed group effects, we find that our key variable, EXPYA, remains significant and of a similar magnitude in both the random and fixed-effects regressions, giving us a robustness check on our estimation[13].

The Hausmann specification test suggests that a systematic difference exists between the random and fixed-effects models, which implies that the fixed-effects estimator is consistent, and the random-effects model is not. Unfortunately, in the

[13] The expya variable in regression (4) is significant at the 12% level, and is indeed significant at the 10% level if we use the 10-year whole period growth rate, rather the yearly average.

fixed-effects regressions human capital not only loses its significance but also changes sign, contrary to economic intuition. The human capital variable also loses its significance in the fixed-effects estimation in the published literature, but maintains its sign. Though the random-effects regression returns a “nicer” result, it seems difficult to argue that we should assume the unobserved factors impacting our growth regressions are not correlated to specific country panels, as the random-effects regression requires. Many attempts have been made to address this negative human capital coefficient, including a quadratic term and possible interaction terms, as well as a reduction of all countries without a full set of observations. However, even in our smallest model, we still include over 100 observations in excess of those used in the previous literature. Moreover, additional regressions run on subsets of the observations based on income levels, suggest that the sign of this human capital variable is quite sensitive to adjustments in the collection of observations. Given the sensitivity of this variable, the greater number of observations we employ, the findings of our specification test, and the methodology used in previous literature, we concentrate our panel analysis on the fixed-effects model.

Given the results of these various model specifications we consider the pooled ordinary least squares and fixed-effects panel regressions with five and ten-year growth panels as our base-line estimations. We include the HC15, EXPYA, and GDP/capita independent variables in this base model as well as our dependent variable of GDP/capita growth averaged per year. This estimation serves as our baseline model in Chapter 3 as well, though modified to include disaggregated EXPYA variables.

VI. Motivation for further analysis

Our empirical analysis has confirmed the earlier findings of Hausmann et al. (2007) on the impact of the complexity of trade on economic growth. Enlarging their study by more than 10 countries and 100 observations we also conclude that a country's increase in the complexity of the goods they export results in higher economic growth. This finding is robust in both magnitude and significance to both a pooled OLS model and a fixed-effects panel model. These results suggest that countries have justification in promoting policies that encourage production diversification, particularly subsidizing new entrants and encouraging entrepreneurship if such actions will increase the "cost discovery" process and ultimately lead to a higher θ_{max}.

The authors of the original study purported that "a country's fundamentals generally allow it to produce more sophisticated goods than it currently produces", making this process both vital and feasible (Hausmann et al., 2007). However the obvious question remains, even if a country is *able* to produce more sophisticated goods that it currently does, what level of sophisticated goods will bring the maximum benefits? Obviously, in the case of Latin America and Import Substitution Industrialization, the ability to produce more sophisticated goods existed, but the resulting industries proved inefficient and overall benefits to growth never materialized. Hence, even if agreement regarding the need for industrial policy did exist among development economists, which it does not, individual country policy makers would still benefit from greater knowledge of those industries most likely to bring about economic growth given their own current state of technological capabilities.

Unfortunately, the information presented thus far does not clearly elucidate a particular pattern between different sectors and economic growth. Though we find a robust relationship between export sophistication and growth, this information does not tell us which of these sophisticated products have the greatest impact on economic performance. Regarding product sophistication, is a higher value always better or could certain products or sectors encompass a greater number of the benefits mentioned in the motivation for this study?

For instance consider primary and resource based product clusters. Given the construction of our EXPY and PRODY variables, we know that products exported by wealthier countries will get higher sophistication scores. This implies that even primary and resource based products exported by wealthy agricultural and resource rich countries such as the United States, Canada, and Australia will have relatively high scores. However, two difficulties arise regarding their inclusion in our previously discussed framework explaining the benefits that accompany product sophistication. First, though wealthier countries may employ higher level production techniques, in commodities our index will be unable to distinguish between different production methods. For instance, the United States, Mexico, and Malawi all produce corn, yet the methods and technologies employed in each country's production differ greatly, making it difficult to assume that our index could capture the overall sophistication embodied in corn production. Second, even if the index did capture a movement toward a more sophisticated agricultural industry one might question the "spillover" benefits to higher level manufacturing.

However, manufacturing industries slightly upstream from primary products, such as food processing, while not as technology intensive as computer chip production would require a set of skills applicable to other industries. Moreover, such movements upstream could be captured by our index if wealthier countries produce relatively more of these slightly-manufactured resource based goods. This type of resource-based manufacturing represents nearly 20% of Chile's exports, the country with the best growth record in Latin America since the 1970's, leading one to question the importance of these sectors in relation to economic growth.

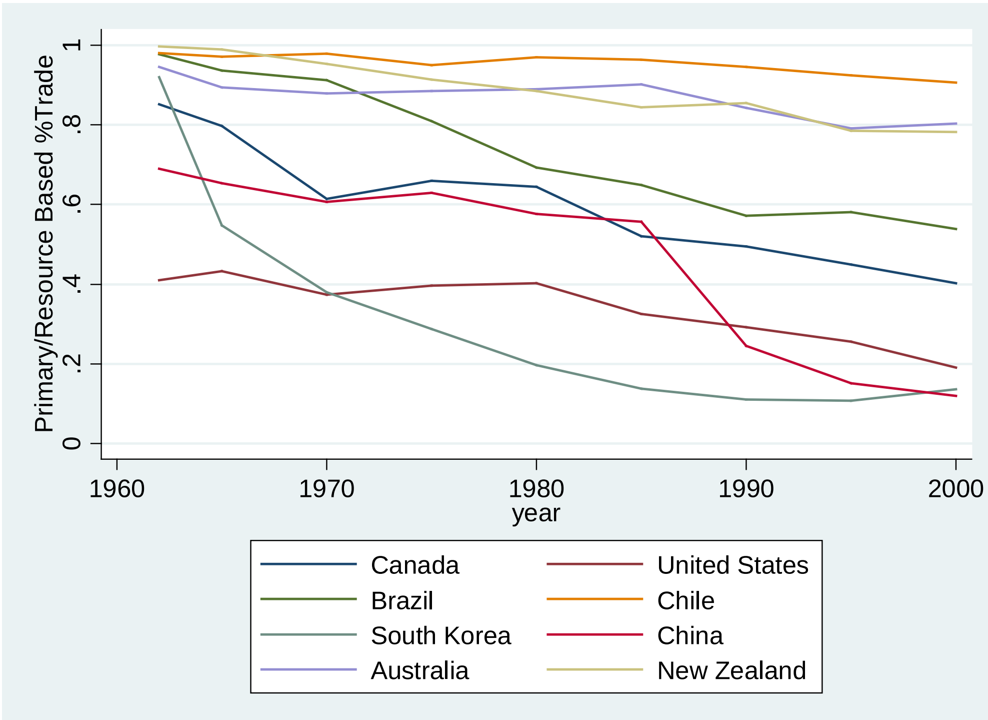


Figure 2.2 - % Trade in primary/resource products

It appears that among at least some countries considerable variation occurs regarding sophistication and a country's main export sectors. Figure 2.2 shows that among the particular countries examined, primary and resource based products composed at least 50% of trade at the beginning of our panel. However, apart from Chile, New Zealand, and Australia, each of these countries has significantly reduced their exports of such goods, with China and South Korea showing drastic reductions. Yet, Figure 2.3 shows that the relationship between exports of primary/resource based goods and export sophistication is not clear. We see that some of our major primary/resource exporters such as New Zealand and Australia, have very high sophistication levels throughout the period. Meanwhile, Chile, which also exports mostly from these sectors, has the lowest overall sophistication score, though it steadily increases. This mixed response is also evident in our larger dataset. Figure B.1 in Appendix B shows a scatter plot between sophistication and percentage trade in primary and resource based products for all our observations. It shows an inverse pattern, but with a great number of outliers. Interestingly, however, the major rise in export sophistication for China, which occurs after 1980, and Korea, which occurs over the whole period, coincide with their dramatic declines in exports from these primary sectors. Though exports of resource based goods allows for high sophistication scores, perhaps major growth in sophistication and subsequent economic growth requires movement into higher level manufacturing sectors.

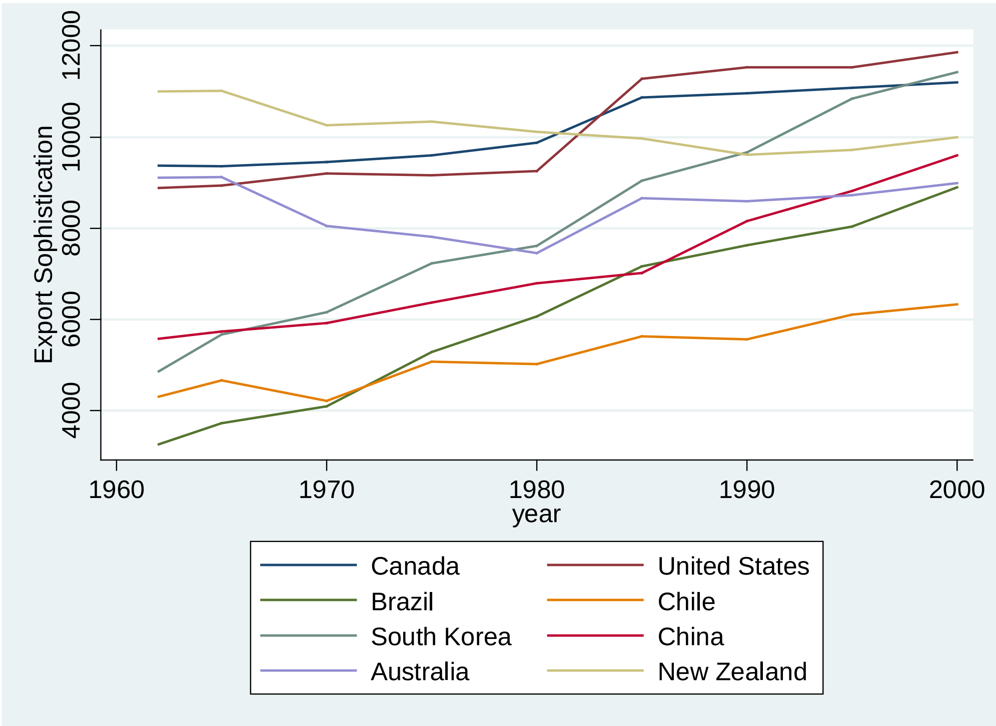


Figure 2.3 – Overall export sophistication

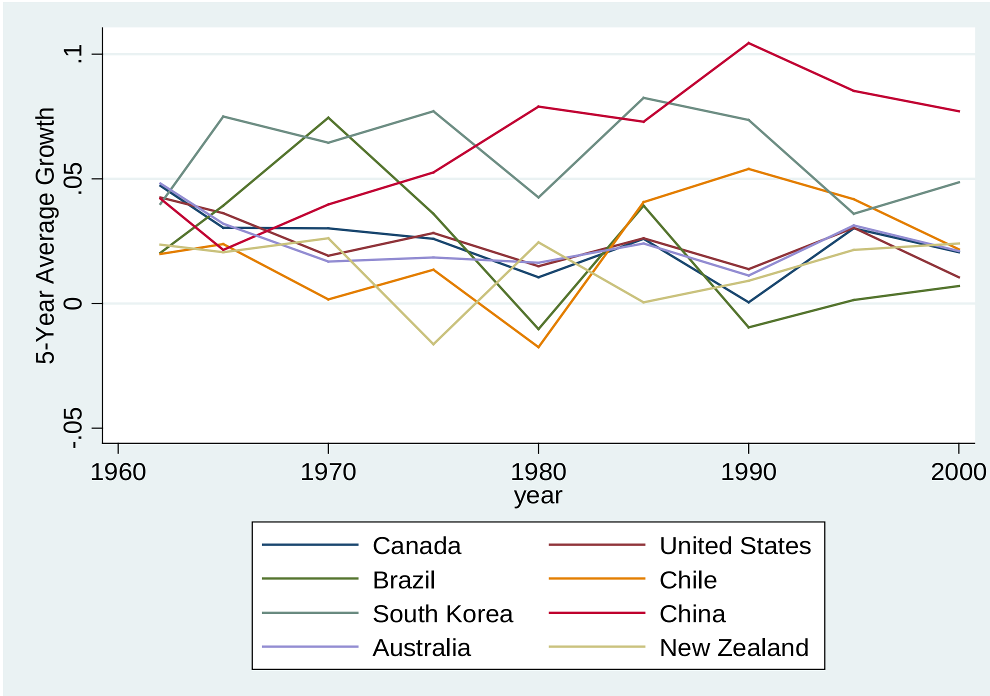


Figure 2.4 – Economic Growth, 5-Year Average

Moreover, an examination of Figure 2.4 reveals that these same countries with varying export patterns and varying sophistication levels also have widely variant growth patterns. Since 1980, the three countries from this group with the strongest growth performance have been China, South Korea, and Chile, countries at opposite ends of the sophistication spectrum. These results elicit two questions regarding the preceding discussion on sophistication and growth. Primarily we need to investigate if these outliers represent an actual trend in the larger data, suggesting that export sophistication at any level can lead to economic growth, as depicted from the Chilean experience. If indeed, export sophistication across a broad range of sectors can lead to economic growth, the next question one should ask is whether a country's current level of sophistication matters in determining which product areas are most beneficial in achieving this growth. An analogy perhaps helps clarify this proposition. Consider all countries on a ladder of development on which a higher position implies higher product sophistication. Should a country's current rung on the development ladder affect the benefits that accrue from reaching for higher rungs? Does every country benefit from reaching for the top or are intermediate steps crucial along the climb? These questions obviously have enormous policy impacts and are of a rather ambitious nature; however, in the next chapter we use our compiled dataset and an export classification system devised by Sanjaya Lall to shed at least some light on this daunting subject matter within the framework of our current study.

CHAPTER III

I. Introduction

Hausmann et al. (2007) examine the impact of product sophistication, proxied by exports, on economic growth. They find a positive, significant, and robust relationship. However, increasing one's overall product sophistication can be achieved through the production of a range of goods from low technology resource based products to electronics and pharmaceuticals. Given the great variation in expense and difficulty associated with transferring from one's current production to these various industries, additional analysis regarding the effect of sophistication within particular product sectors on economic growth would be most enlightening. Moreover, the countries most in need of sound strategies for achieving economic growth are also those most likely to have difficulty quickly transitioning their industrial sectors into the production of new goods, and hence could benefit most from knowledge of the sectors with the most significant relationship with growth.

The objective of this chapter is to extend the work of Hausmann et al. (2007) creating an export sophistication product ranking within five product categories. The categorization we use comes from Lall (2000). Our particular contribution to this body of knowledge is the development and analysis of a number of methods for determining sector sophistication. Selecting the best of these methods we investigate the top ranked countries and products in each of our export categories, examining what particular factors drive our sophistication ranking. We then use these country sophistication scores to discover the relationship between economic growth and sophistication within product sectors. Finally, we attempt to deduce the impact of a country's current level of development (proxied by income, and HDI rankings) on this relationship between sector sophistication and growth.

Unfortunately, the resource-based manufacturing success in Chile and its subsequent economic growth that motivated much of this discussion appears to be a unique case. Indeed, neither sophistication in the primary nor resource-based sectors has a significant relationship with growth for countries in any income range. However, focusing one's exports on the low-tech sector, which includes textiles, garments, and basic metal manufacturing, seems to be beneficial for countries in a wide range of development. Though the magnitude of its effect is not great, export sophistication in the low-tech sector has a very significant and robust relationship with economic growth. Finally, as one might expect, for the 20 wealthiest countries in the world, the only significant growth benefit found from export sophistication comes from the high-tech sector, including the most advanced electronics, pharmaceuticals, and aviation equipment.

II. Productive Sector Classification

A number of ways exist in which to divide a country's outputs into productive sectors. A recent paper by Kaplinsky and Paulino presents a concise table listing nearly twenty different published classifications, the main criteria used in each paper, and whether that criteria is analytical or based on personal judgement. The criteria range from readily observed components such as factor-intensities and the type of product produced, to more abstract notions such as the processes involved in production, innovations in the those processes, research and development norms in the industry, and necessary skills. The authors identify three types of sector classification "those focusing on product characteristics (income elasticity, for example), those on factor content (notably capital and labour intensity), and those targeted at innovation intensity" (Kaplinsky & Paulino, Innovation and Competitiveness: Trends in Unit

Prices in Global Trade, 2005). The paper itself attempts to examine innovation within sectors by measuring the unit-price of outputs in those sectors.

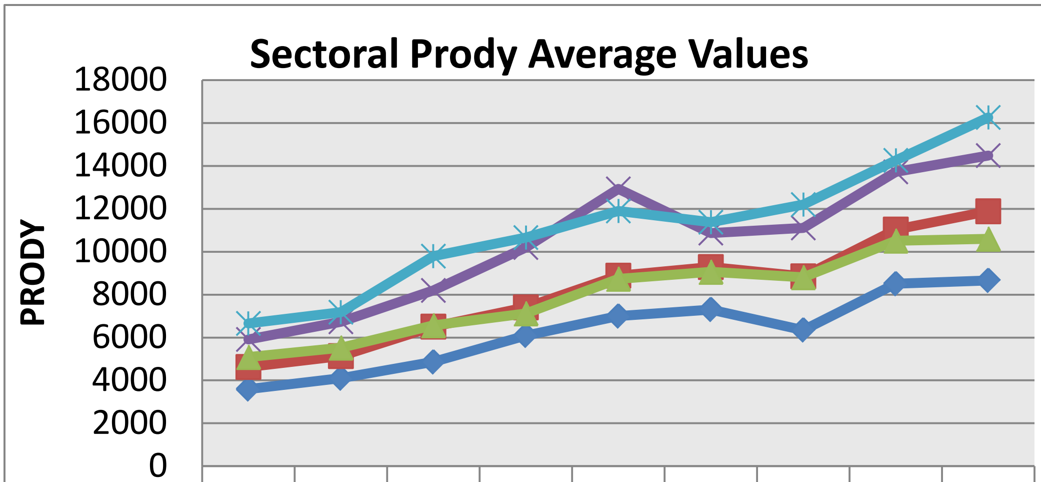
Recall that the theoretical model which motivates our empirical work suggests that searches for more productive industries and the spillover effects, in terms of process knowledge and technology expertise, which arise from developing those more productive industries, drive the relationship between export sophistication and growth. Hence, for the purpose of this study sector classifications based on innovation seem most applicable. Among those classifications, we have chosen to use Sanjaya Lall's particular methodology described in, *The Technological Structure and Performance of Developing Country Manufactured Exports, 1985-1998*. We have chosen this particular classification both because the author's views on the capability approach motivated this study and should inform any classification we use and since he draws distinctions based on SITC three digit product codes his ranking is easily configured to our own dataset[14].

Table 3.1 – Lall's sector classfication

1) Primary products
2) Resource based manufactures
    a) Agro/forest based products
    b) Other resource based products
3) Low technology manufactures
    a) Textile/fashion cluster
    b) Simple medal production
4) Medium technology manufactures
    a) Automotive products
    b) Medium technology process industries
    c) Medium technology engineering industries
5) High technology manufactures
    a) Electronics and electrical products
    b) Aircrafts and pharmaceuticals

[14] For a comprehensive listing of the products included in each category see (Lall, 2000).

Lall's classification, which we describe in Table 3.1 above, attempts to divide products by the technological process involved in their production and the skills necessary to efficiently carry out this process. Hence goods in the first category, primary products, require very little manufacturing and a country's comparative advantage in their production normally depends on natural endowments. As one proceeds up the sector rankings, the production process becomes more skill and technology intense forcing countries to have a higher level of "capability" in order to be competitive in producing such goods. If product sophistication does involve the use of higher level skills and technology intensive processes, as we claim it does, then the PRODY sophistication index should increase with succeeding sector classifications. Figure 3.1 shows precisely this.



	1962	1965	1970	1975	1980	1985	1990	1995	2000
pprody	3598.18	4101.06	4858.36	6095.57	6996.2	7303.34	6348.64	8503.7	8657.15
rbprody	4632.49	5135.11	6507.7	7401.43	8887.7	9279.94	8850.72	11025.4	11878.8
ltprody	5083.08	5520.59	6562.26	7119.69	8736.42	9059.89	8807.16	10514.1	10602.4
mtprody	5911.55	6729.36	8199.16	10197	12927.4	10869.1	11110.7	13725.5	14476.8
htprody	6662.86	7175.87	9785.91	10659.7	11891.3	11380.1	12197	14254.2	16258.3

Figure 3.1 – Sector PRODY average values

We can see that though some overlap exists, products associated with higher technology sectors in Lall's classification have higher product sophistication scores on average. Figure 3.1 reports the average of all product sophistication scores within each category for each five-year period. Recall that for the purposes of our regressions we use product sophistication scores averaged over the entire 39 year panel, however, this graph shows that the correlation between Lall's sectors and our sophistication index holds throughout the sample. Closer examination reveals that while a clear distinction exists between primary products and the two middle sectors, and between the middle sectors and the top sectors, significant overlap occurs among the low-tech and resource based categories and the medium/high-tech categories. Our product sophistication scores would suggest that these overlapping sectors embody very similar technological processes.

III. Export Sophistication by Sector

In order to analyze export sophistication within sectors modifications must be made to the original EXPY indices. The product sophistication variable, which ranks goods according to the wealth of the countries that export them, remains unchanged in our sector analysis. However, as depicted in equation (2.1), the sophistication level of sector *j* in country *k* essentially takes a partial sum of the original EXPY variable for all *i* goods in sector *j*. Each sector's sophistication level comprises a sum of the sophistication of all products exported by a particular country in that sector weighted by the percentage of the country's overall trade which each product represents.

(2.1) $$EXPY_{kj} = \sum_i \frac{x_{ki}}{X_k} * PRODY_i, \ \forall \ i \ \in j$$

(2.2) $$EXPY_{kj} = \sum_i \frac{\frac{x_{k,i}}{X_k}}{\sum_i \frac{x_{k,i}}{X_k}} * PRODY_i, \; \forall\, i \in j$$

Weighting products by their sophistication score undoubtedly makes this measure reflect increased product sophistication within sectors. However, because this sector EXPY is a partial sum weighted by a country's own value share, which must sum to one over all products, shifting ones trade into new sectors will automatically increase sophistication within that sector. Hence, this index reflects both a quality and quantity measure. Seeking an index based purely on sophistication we also devised a methodology weighting product sophistication levels by value shares within only that sector rather than overall value shares, see equation (2.2). This, in essence, weights the sophistication level of each product in a country's sector sophistication score by the percentage of a country's trade represented by that product within only that particular sector. Figures 3.2 and 3.3 below show the top ten countries by high-tech export sophistication rank using the two different methods.

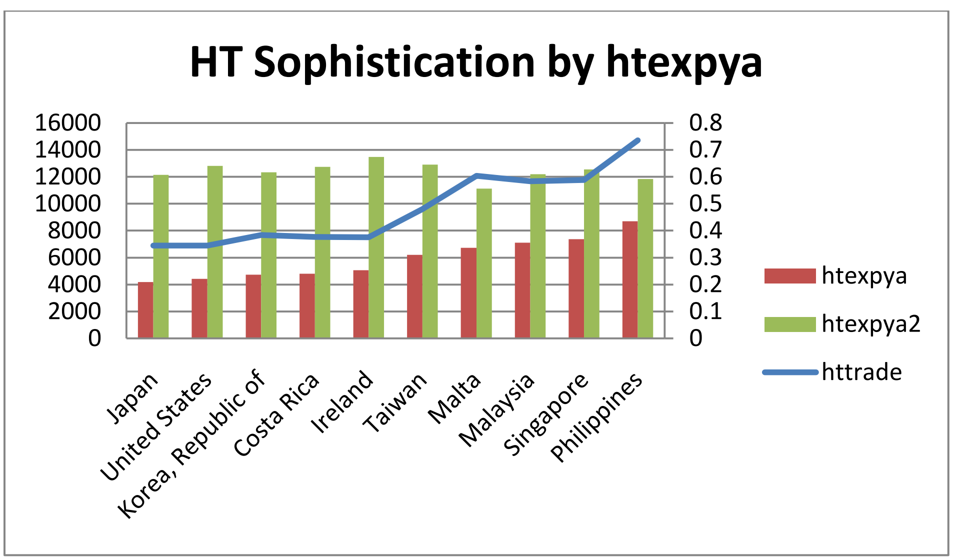


Figure 3.2 – Top ten countries by high-tech sector sophistication, methodology 1

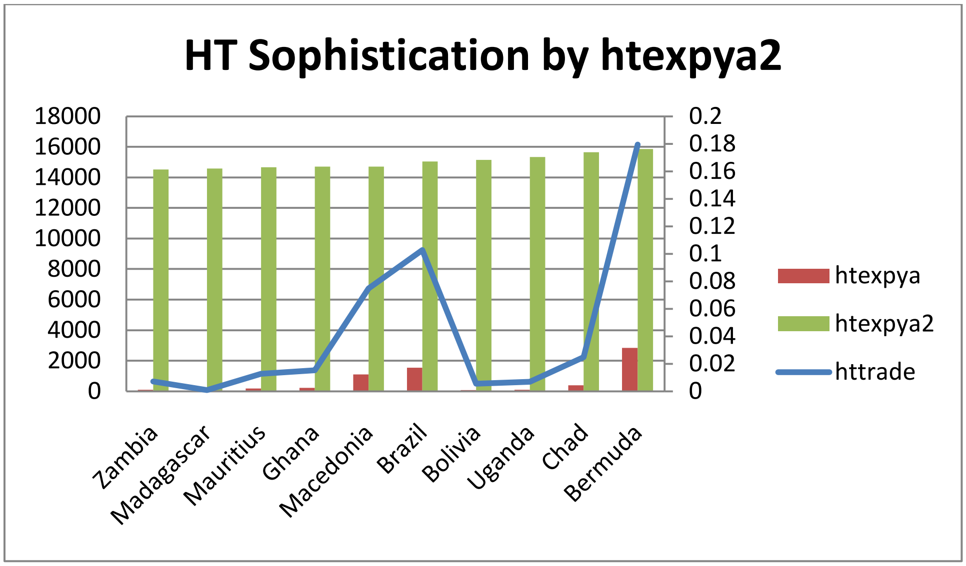


Figure 3.3 – Top ten countries by high-tech sector sophistication, methodology 2

Using overall value shares as our weight seems to reflect a better overall measure of product sophistication comparing Figures 3.2 and 3.3. We can see that using this method, export sophistication in the high technology sector is indeed highly correlated with a country's percentage trade in that sector. However, Figure 3.2 displays countries' sophistication rank using both indices and shows that the countries receiving top scores when weighted by overall value shares also have high levels of sophistication when weighted by within sector value shares. The converse does not appear to be true as show in Figure 3.3. None of the leading countries ranked by the second methodology have high scores in the first ranking, and only three of the top countries export more than 2% of their overall trade in the high technology sector. It is unlikely that such a small percentage of a country's overall export sector would embody the spill-over benefits and productivity gains that we seek to reflect in this ranking. However it is important to note that some discrepancies with common notions of export sophistication still exist when using overall value shares, such as the

Philippines higher ranking than the United States. Again, this is because our ranking inevitably rewards countries with exports concentrated in particular sectors. Despite these limitations weighting by overall value shares best captures the measure of sophistication pertinent to this particular study. The creation of a more precise measure of sector sophistication could be the topic of future research[15].

IV. Analysis of Country and Product Sophistication by Sectors

Now that we have identified a particular methodology for ascertaining sophistication within productive sectors, this section examines those products and countries with the highest sophistication rankings looking for patterns overtime. In order to illustrate the manner in which products receive their scores, we examine the top and bottom five products within the primary product sector. Figure 3.4 shows that a great deal of variation exists between the highest and lowest ranked products in this sector. Table 3.2 sheds some light on this variation showing the five top exporters, by weighted value shares or revealed comparative advantage, for the highest and lowest ranked products, a special type of wheat and shellac. The first column shows each country's weighted value share in each product. Given the method for determining product sophistication, each country's weighted value share is multiplied by its GDP/capita to produce the PREPRODY value, which summed together give the product its overall sophistication level. A quick glance at table 3.2 reveals that the production of goods with extreme sophistication values is concentrated in either wealthy or poor countries.

[15] An additional attempt to combine both methodologies consisted of re-weighting the expy values constructed using the second methodology by overall value shares. This resulted in a slightly different ranking scheme, but a similar relationship between sector sophistication and growth.

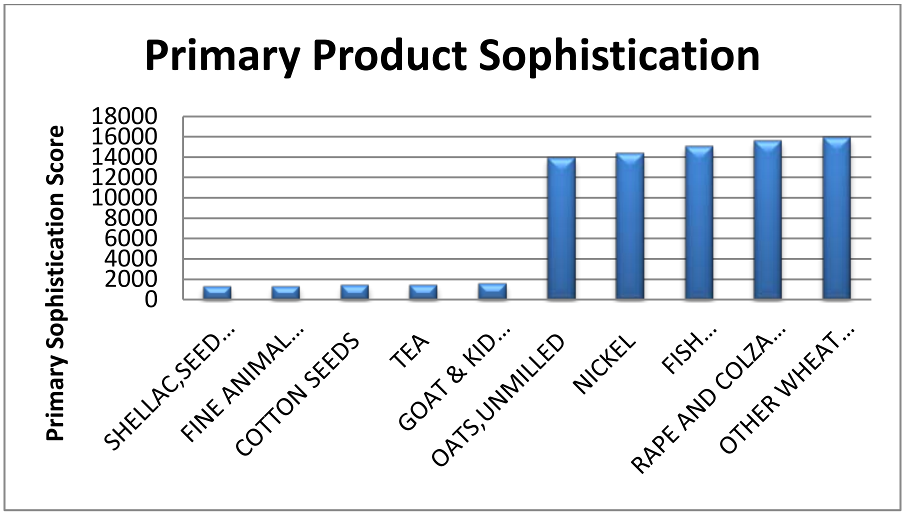


Figure 3.4 – Highest/lowest ranked goods by sophistication, primary products

Table 3.2 – Components of sophistication for primary products

	Country	WVS	PREPRODY	PRODY
WHEAT	United States	.0597758	1721.714	19679.67
	France	.0703783	1518.517	19679.67
	Argentina	.0760705	834.4725	19679.67
	Canada	.110547	2446.757	19679.67
	Australia	.4514494	9923.915	19679.67
SHELLAC	Senegal	.0292799	46.00949	1005.653
	Ethiopia	.0345958	25.09475	1005.653
	Sudan	.088462	92.68247	1005.653
	Somalia	.1075862	73.33397	1005.653
	Chad	.68514	568.3304	1005.653

As discussed previously it is not immediately evident that production of certain types of wheat or rapeseed, the highest ranked products in the primary sector, necessarily requires more skills and abilities to efficiently employ technologies than the production of shellac or tea leaves. However, analysis of tables A.4 – A.7 in Appendix A reveals some differences between the types of products ranked at the top and bottom of the sophistication index for the resource based through high-tech sectors. Thorough analysis of these different product categories obviously requires knowledge of the industrial processes used in their production, an endeavor beyond the scope or expertise of this study. Moreover, our aggregation to the four digit product level, a condition of our dataset, does not allow for a precise investigation of particular products.

However, in light of these difficulties we recall that our sector sophistication variable reflects both increases in the quantity and quality of goods produced in a given sector, as will be made apparent in the next section. Given the overall upward trend in sophistication as one moves to higher level sectors, this quantity component also provides an indication of the precise level of overall sophistication a country has achieved, as countries can increase their sophistication by producing either more sophisticated goods within a category or by producing goods in a higher level category. When we address the growth regressions in the final section of this chapter, we will revisit this idea, interpreting our estimation results as a combination of within and between sector sophistication.

Having considered how the products achieve their various rankings, we now examine countries' sophistication within product sectors. Beginning again with the primary products sector in 1962, the first year for which we have available data, Figure 3.5 displays the five countries with the lowest and highest sophistication scores in this sector. As previously mentioned, our sector sophistication index combines both a quantity and quality dimension so the following figure presents a number of measures that attempt to highlight these various components. PEXPYA is our sector sophistication variable, represented by the blue bar graph. Clearly, there exists significant variation of primary product sophistication among the countries in our study, with the bottom five countries receiving a score near zero. Ptrade represents percentage of overall trade in primary products for each country, in other words it depicts the importance of primary products in a country's export regime. Meanwhile, PEXPYA2 denotes each country's export sophistication score using within sector value shares, removing the "quantity" metric from our index. In addition, the PEXPYA2 averaged over all countries in our sample is also depicted on the graph as a base for comparison.

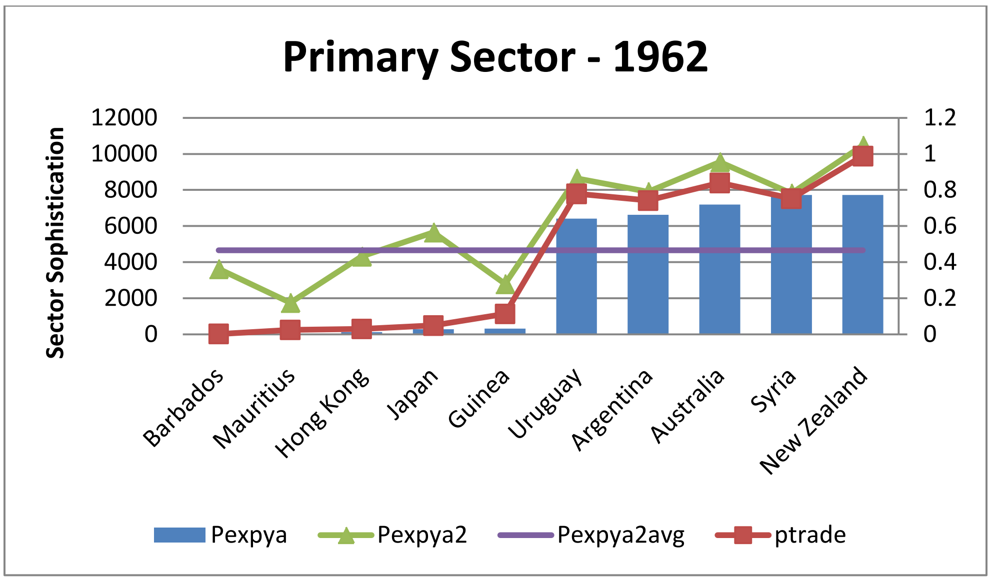


Figure 3.5 – Highest/lowest ranked countries by primary product sophistication

As expected, quantity clearly plays a role in our index such that the top five countries each have over 60% of their trade in primary products. However, they also produce more sophisticated products relative to the average, as indicated by their PEXPYA2 values. Recall that PEXPYA2 weights the sophistication of products in each country's primary sector by the sector value shares, rather than overall value shares. This allows for countries such as Japan, which has less than 5% of its overall trade in the primary sector, to receive a relatively high sophistication score in PEXPYA2. However, in our index Japan has one of the lowest overall primary sector sophistication scores precisely because it exports so few of these products. Therefore, our index reports a combination of these factors, such that for a country to receive a high sophistication score in any one sector, that sector must be important in the country's overall trade basket and the country must produce more sophisticated products from within that sector.

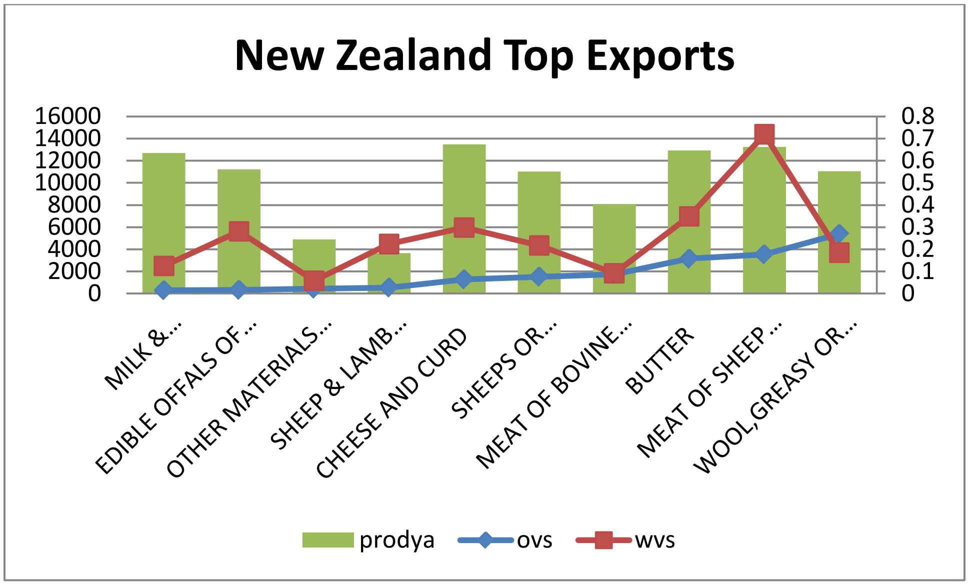


Figure 3.6 – Top ten exports by value, New Zealand, 1962

An analysis of New Zealand's top ten exports in the primary product sector confirms our suppositions regarding the requirements for a high sector sophistication score in our index. Figure 3.6 depicts the ten goods that represent the greatest portion of New Zealand's trade in 1962, as represented by the own value share line (ovs). Interestingly, the products for which New Zealand's exports represent a large portion of the world's exports, are also those products with the highest PRODYA or product sophistication scores. Thus, New Zealand's rank as the most sophisticated exporter of primary products reflects both its concentration of exports in primary products and the high sophistication rank associated with the products of which it is a relatively large world exporter. Similar patterns exist with respect to the remaining four sectors, which appear as Figures B.3-A.9 in the appendix.

We can also examine our sophistication ranking by income groups over the forty-year period in search of trends by sector. Given what we have shown our index to represent, we can interpret these trends as a measure of the importance of each sector in the three income groups we consider as well as a measure of the sophistication of the products within those groups. Figures 3.7 – 3.11 show the average country sophistication score for each sector divided into three categories by GDP/capita values. Ranking 1 refers to the third of the countries in our sample with the lowest GDP/capita values. Figures 3.7 and 3.8 show that little has changed in the overall sophistication of the primary and resource-based categories, as one might expect, but the distribution of the sophistication in primary products has transferred from the rich countries (group 3) to the poorer countries (group 1). This suggests that wealthier countries have switched the focus of their exports away from primary products to higher level sectors, which is precisely what Figures 3.10 and 3.11 show. In the medium and high-tech sectors, the wealthiest third of our sample has seen an enormous surge in product sophistication over the past forty years, while the middle third shows some gains, and the bottom third nearly none. However, in the low-tech sector, a most interesting pattern emerges in which the wealthy countries first rise and then fall in product sophistication, while closely followed and eventually overcome by the middle-income group. The lowest ranked countries by GDP/capita also see substantial gains in this low-tech sector, suggesting that this level of sophistication represents an achievable step on the development ladder, and as later regressions show, perhaps a very worthwhile step in terms of growth.

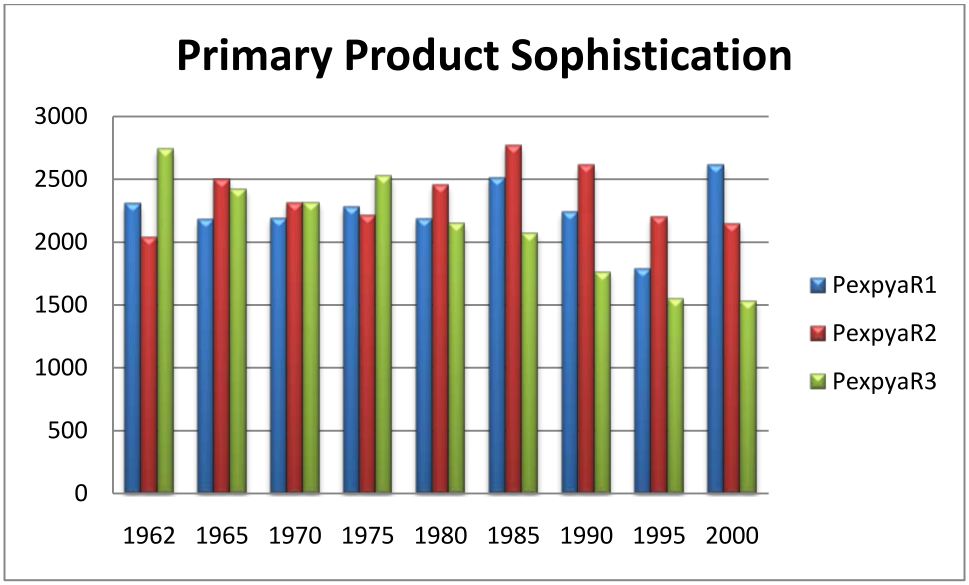


Figure 3.7 – Primary sector sophistication, by GDP/capita group

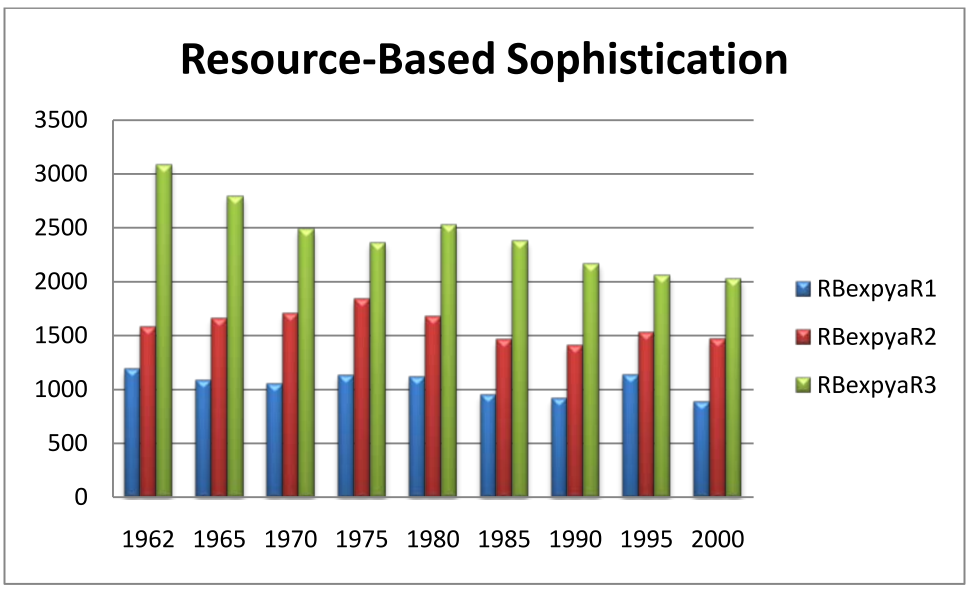


Figure 3.8 – Resource-based sector sophistication, by GDP/capita group

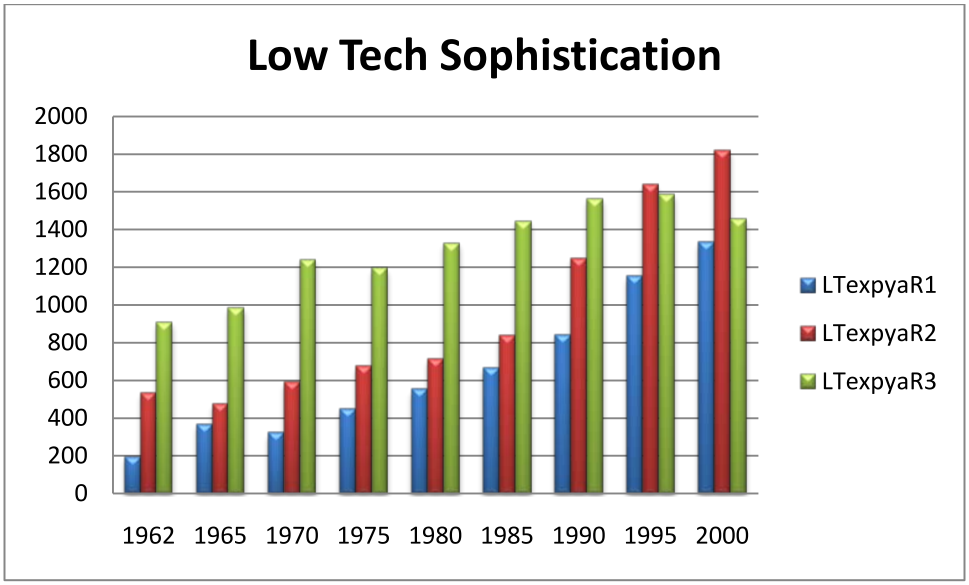


Figure 3.9 – Low-tech sector sophistication, by GDP/capita group

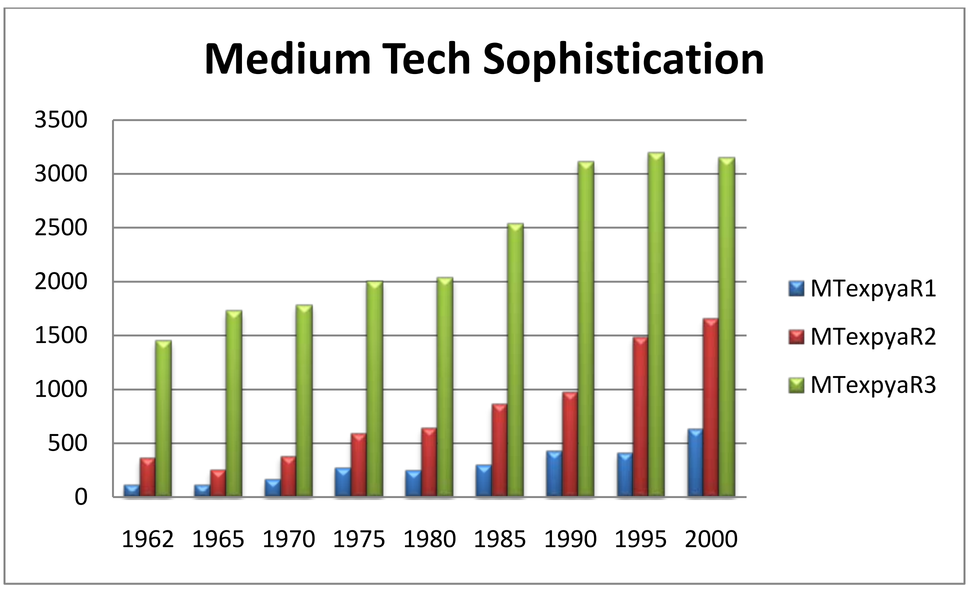


Figure 3.10 – Medium-tech sector sophistication, by GDP/capita group

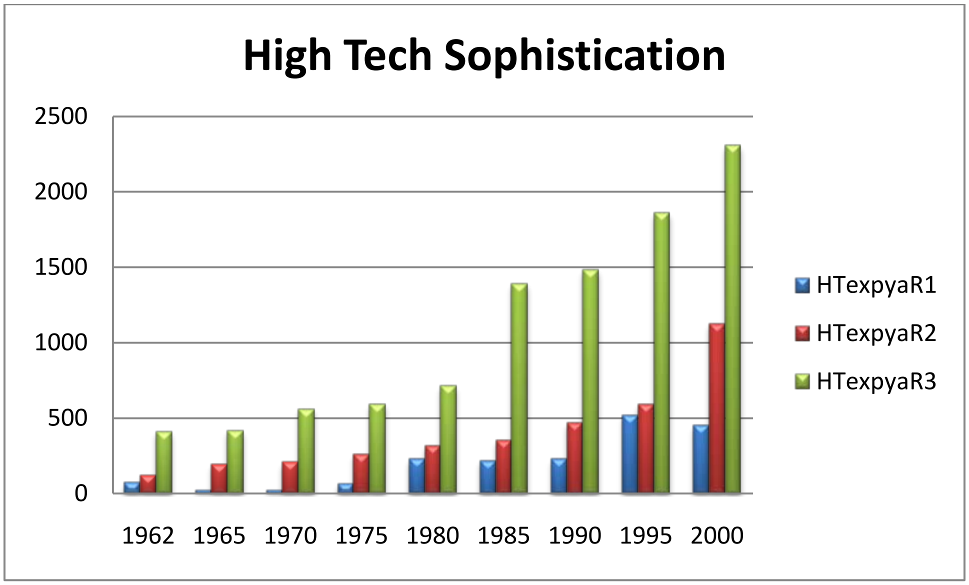


Figure 3.11 – High-tech sector sophistication, by GDP/capita group

Having analyzed our sector sophistication index for trends in our overall sample we now return to the original set of countries that motivated this section. Figures 3.12-3.13 below show that Chile's sophistication in the primary and resource based sectors, unique from the group, increased over our sample period. As expected this reflects both a continued reliance for Chile on copper exports, but also a buildup in manufactured food and beverage products. However, Figures 3.14-3.16 display a very distinct pattern in the quickly growing economies of South Korea and China. South Korea develops a very sophisticated low-tech industry during the 60's and 70's followed by a gradual and then steep decline. China's exports show a similar patter, but begin their increase about ten years later than those of its South Korean neighbor. Meanwhile, the rest of the countries in our sample show little change in their low-tech sectors. In the medium-tech sector we see both countries again developing more sophisticated industries, but nearly ten years after their respective build-ups in the low-tech sector. This step-by-step process to higher levels of sophistication completes itself in Figure 3.16 where South Korea and China both show significant increases in their high-tech sophistication scores, at least five years following their rise in the medium-tech sector.

These country-specific patterns present two questions, which we will address in the final section on growth regressions. Specifically, they again bring into question whether or not primary and resource-based sector sophistication can indeed stimulate growth overall, at least as evident by our collection of data. In addition, they urge one to consider the possibility that a country's current level of development affects the level to which it can successfully increase its product sophistication.

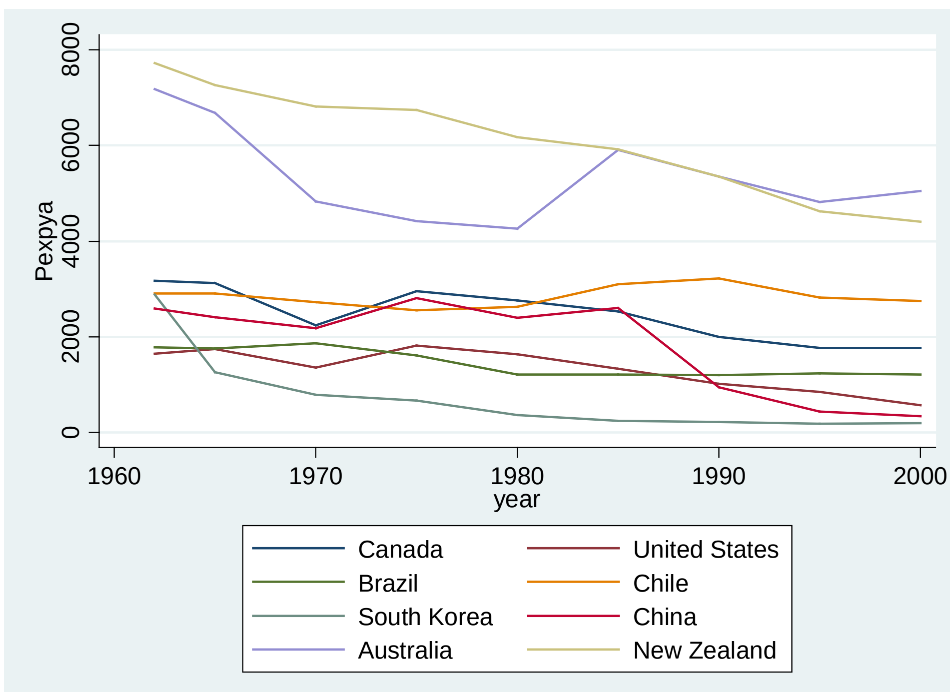


Figure 3.12 – Primary sector sophistication, 1962-2000, select countries

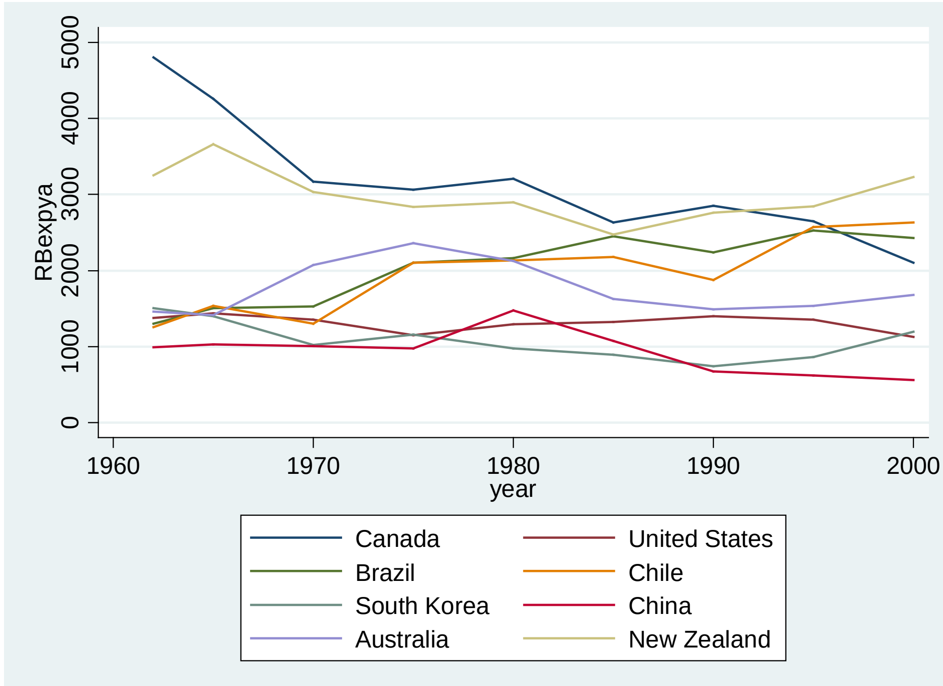


Figure 3.13 – Resource-based sector sophistication, 1962-2000, select countries

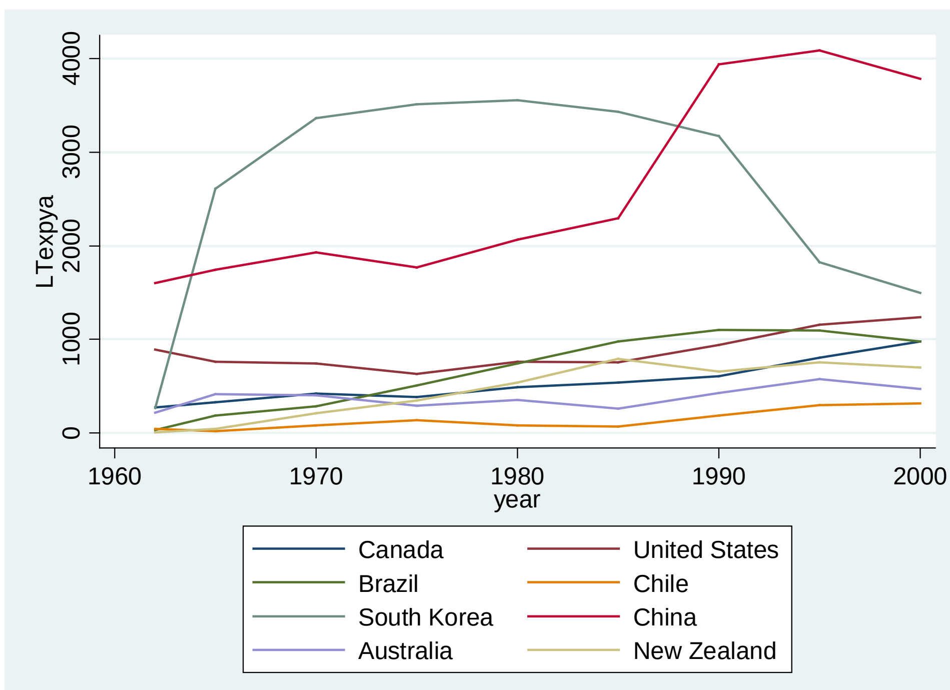


Figure 3.14 – Low-tech sector sophistication, 1962-2000, select countries

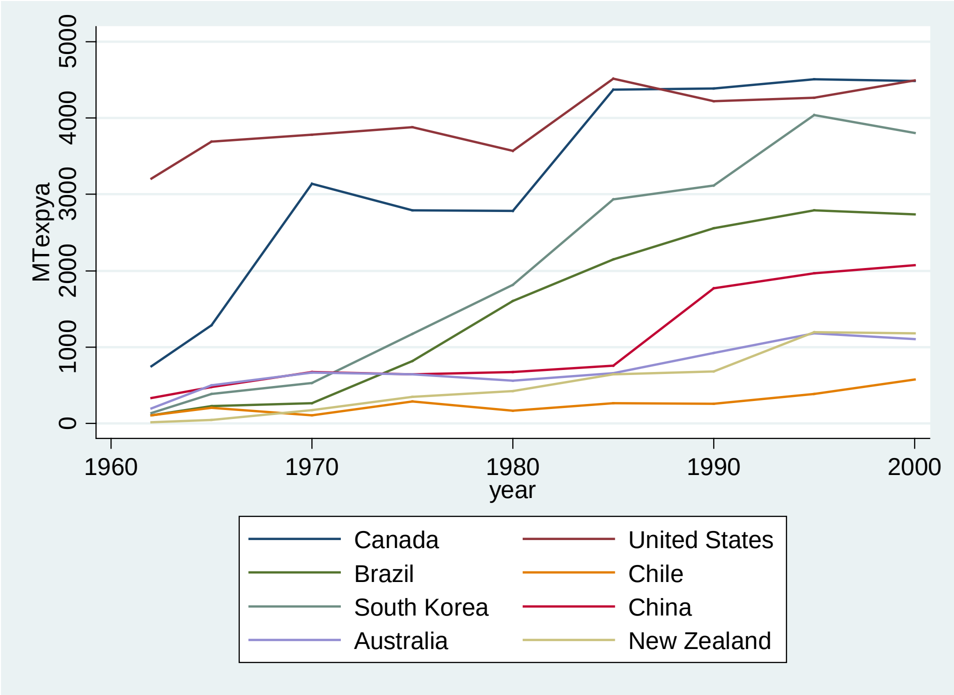


Figure 3.15 – Medium-tech sector sophistication, 1962-2000, select countries

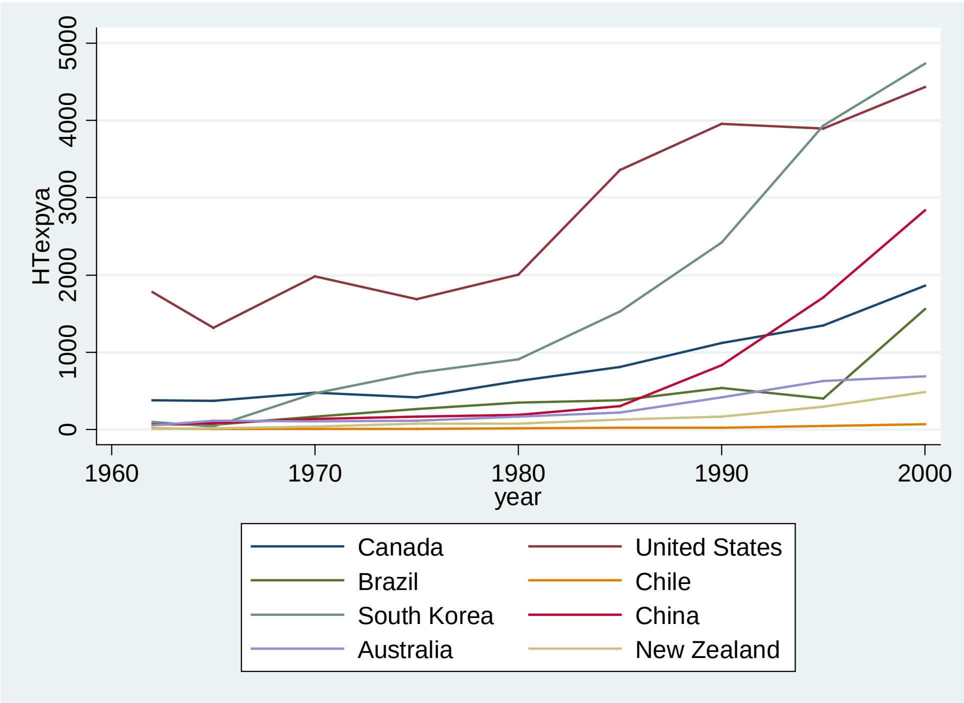


Figure 3.16 – High-tech sector sophistication, 1962-2000, select countries

IV. Model Specification

We again appeal to Hausmann et al.'s (2007) "What you export matters" for the theoretical underpinnings of our econometric model. Drawing from a larger literature on technology spillovers and learning by doing, the basis for their model is that perfect knowledge regarding the efficiency of industrial processes can only be known after they have been implemented. In their paper they discuss the dynamic process that occurs as an economy invests in a search for more productive sectors, whereby as higher productivity industries emerge they generate greater expected profits for successive waves of entrepreneurs. These entrepreneurs, stimulated by the prospects of higher returns, then continue to invest in new sectors revealing yet more competitive industries, only constrained by the overall human skill level in the economy.

Therefore, their model sees growth as a function of human capital, the level of currently discovered production (EXPY), and GDP/capita, as seen below.

$$(3.1) \quad \text{Growth} = f(\text{hc, EXPY}_{,}\ \text{GDP}_0)$$

Our model, then, disaggregates the level of currently discovered production into five unique components, yielding a growth function as follows:

$$(3.2) \quad \text{Growth} = f(\text{hc, Primary EXPY, Resource-Based EXPY, Low-Tech EXPY, Med-Tech EXPY, High-Tech EXPY, GDP}_0)$$

In order to test this relationship empirically we assume a linear relationship and take the logarithm of the independent variables, arriving at the following equation, where the dependent variable is percentage change in GDP/capita over the period:

$$(3.3) \quad Y = \alpha + \beta_1 \log(PEXPYA) + \beta_2 \log(RBEXPYA) + \beta_3 \log(LTEXPYA) + \beta_4 \log(MTEXPYA) + \beta_5 \log(HTEXPYA) + \beta_6 \log(hc15) + \beta_7 \log(GPD_0)$$

As before, we define human capital as the average years of schooling for everyone in the population above 15[16]. The source for our human capital measure comes from Barro and Lee's 2000 study on educational attainment. Again per capita GDP figures come from the Penn World Tables. Our theoretical model suggests that increases in any of the EXPY variables and human capital should increase our annual percentage growth, while increases in initial per capita GDP likely cause percentage growth to decrease.

As stated previously, in their econometric analysis, Hausmann et al. (2007), include time dummies in each of their growth regressions. This makes sense considering the great number of external factors affecting overall GDP growth in any given year, particularly global bust and boom cycles. Moreover, an F-test confirms their pertinence so we include them in our analysis. Additional tests, including a goodness of fit test using adjusted R squared and Bayesian and Akaike Information Criteria for the possible inclusion of quadratic terms for human capital and sector sophistication variables as well as interactions among human capital and GDP/capita suggested that these were unnecessary modifications. See Appendix C for details of these tests. See below the final model for estimation, where δ represents the coefficient on the time dummy, d represents the dummy variable for each period, and a dummy for the first period has been excluded to avoid multi-collinearity or a "dummy trap". Additional tests for normality, non-stationarity, heteroskedasticity, and

[16] Once again, data is available for the average years of education for population over 25, however, there are fewer observations and no theoretical reasoning for the choice of 25 over 15.

serial-correlation have been completed and suggest heteroskedasticity to be the only problem. Hence in the proceeding section estimation results are reported with White's robust standard error to ensure consistent estimators. Again, details of these tests can be found in Appendix C.

$$(3.4) \quad Y = \alpha + \beta_1 \log(PEXPYA) + \beta_2 \log(RBEXPYA) + \beta_3 \log(LTEXPYA) + \beta_4 \log(MTEXPYA) + \beta_5 \log(HTEXPYA) + \beta_6 \log(hc15) + \beta_7 \log(GPD_0) + \delta_2 d_2 (1965) + \delta_3 d_3 (1970) + \delta_4 d_4 (1975) + \delta_5 d_5 (1980) + \delta_6 d_6 (1985) + \delta_7 d_7 (1985) + \delta_8 d_8 (1990) + \delta_9 d_9 (1995) + \delta_{10} d_{10} (2000)$$

V. Sector Sophistication and Economic Growth

All regressions have been estimated using Stata version 9.1. Table 3.3 shows the summary statistics for all the variables used in the regressions that follow. Some countries in our sample do not have exports in every sector throughout the panel, which results in non-uniform observations. As one would expect, the highest number of observations occur in the primary products sectors with the lowest occurring in the med-tech and high-tech sectors.

Table 3.3 – Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Pexpya	1149	2317.398	2066.499	9.388059	8843.282
RBexpya	1119	1688.626	1410.479	2.947257	9176.173
LTexpya	1079	997.4322	1229.359	0.510171	7031.683
MTexpya	974	1144.056	1497.221	2.74711	8346.855
HTexpya	1027	558.2066	1079.568	0.421322	8696.062
HC15	858	5.101235	2.851997	0.12	12.05
gdpc	1150	7285.319	8206.361	170.55	67188.32

Table 3.4 – Export sophistication by sector and growth

	(1) Pooled - 5	(2) Fixed - 5	(3) Pooled-10	(4) Fixed - 10
VARIABLES	gdpg5a	gdpg5a	gdpg10a	gdpg10a
lnhc15	0.00828***	-0.0153**	0.00751***	-0.0176**
	(0.00296)	(0.00671)	(0.00285)	(0.00696)
lngdpc	-0.00561*	-0.0129	-0.00687***	-0.0204***
	(0.00311)	(0.00900)	(0.00224)	(0.00455)
lnPexpya	-6.89e-05	0.00196	-0.000375	-0.000272
	(0.00169)	(0.00407)	(0.00129)	(0.00304)
lnRBexpya	0.00224	0.00174	0.00305	-0.000360
	(0.00173)	(0.00317)	(0.00206)	(0.00281)
lnLTexpya	0.00612***	0.00549**	0.00447***	0.00307**
	(0.00211)	(0.00219)	(0.00134)	(0.00151)
lnMTexpya	-0.00379	-0.00184	-0.00119	0.00101
	(0.00289)	(0.00265)	(0.00147)	(0.00247)
lnHTexpya	0.00265*	0.00188	0.00185	0.00130
	(0.00146)	(0.00149)	(0.00122)	(0.00138)
Constant	0.0383	0.109	0.0407*	0.200***
	(0.0318)	(0.104)	(0.0227)	(0.0581)
Observations	730	730	413	413
R-squared	0.209	0.185	0.256	0.303
Countries		107		106

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.4 shows our initial growth regression comparing pooled ordinary least squares and fixed-effects panel regressions for both five and ten year panels. Similar to our analysis in chapter 2 we find a negative ` effect from increases in initial GDP/capita and a positive impact from human capital in the pooled model. However, in the fixed-effects model, which allows for different effects within each country the human capital variable turns negative, suggesting that its strong positive relationship with growth may only exist in a subset of the countries in our sample. Regarding our sophistication variables, it appears that only the low-tech sector has a robustly significant relationship with growth evident in each of the four model specifications.

While the magnitude of this effect, 0.003-0.006, represents only a fraction of the positive significant relationship we found with overall product sophistication in Chapter 2, its robustness within these four regressions as well as several others in the proceeding analysis, serves as an important indicator of its impact on growth.

Following our theoretical approach of cost discovery, this would suggest that the discovery of higher productivity industries in the low-tech sector does indeed begin a dynamic process of investment in new technologies that leads to higher economic growth. Meanwhile, when applied to the technology spillover literature these results imply that the development of the skills and expertise necessary for success in the low-tech sector provides a platform for continued growth in pursuits with higher levels of sophistication both within the low-tech category and beyond.

However, it may be that this relationship between sector sophistication and growth depends on one's current level of development, as we proposed previously. Hence, we test this proposition in a number of different ways. All regressions for this analysis appear in Appendix A. First, we divide our sample of countries into three groups based on their human development index rankings, which considers a number of factors including life-expectancy, literacy, and sanitation. This provides us with one measure of development; however, because the rankings have not been in existence throughout the whole period covered by this study, the latest rankings are used throughout the panel. The index is unique in that it places such weight on the health, education, and life-expectancy scores that some relatively poor countries appear in the top groups. Our regression results show that dividing the sample into these subgroups causes the low-tech sector to lose its significance in all but the highest ranked group, indicating that this positive relationship between LTEXPYA and growth requires a minimum level of development.

Considering the possibility that a country's wealth may be more important in establishing the thresholds for sector sophistication capabilities we next examine these growth regressions by income level. Again the sample of countries has been split into three different categories with separate regressions run in each group. Interestingly, for the group with the highest per capita incomes, a group of the 20 most highly industrialized countries ($31,000 – 20,000), the significance of the low-tech sector sophistication in determining growth disappears. Instead, the high-tech sector, composed of the most sophisticated products overall, such as electronics, pharmaceuticals, and aircrafts, appears significant in each of the four model specifications. Throughout the five and ten year regressions with pooled OLS and fixed –effects, a 10% sophistication increase in the high-tech sector increases GDP/capita by between .5 and 1.4 tenths of a percentage point. This confirms our earlier suspicions that the main benefits of reaching for the highest levels of sophistication accrue to a very wealthy subset of countries. Meanwhile, sophistication in lower end sectors appears futile for this rich group. This result is particularly interesting given that Hausmann et al. (2007) found that increases in overall product sophistication has no significant affect in OECD countries. Thus, the growth impact from product sophistication must be highly concentrated in the high-tech sector.

However, the low-tech sector continues to play a positive and significant role in both the pooled and fixed-effects models for five and ten-year panels in the remaining income categories. Appendix tables A.10 and A.11 show that as the income level falls the lower level sophistication sector that includes textiles and basic metal production again has a significant and robust relationship with GDP/capita. This sector has obviously played an important role in economic development over the years. In their paper on the importance of discovering production efficiencies through practice, Rodrik and Hausmann (2003) discuss the spreading of textile industries in industrializing countries from early developers such as Britain, the United States, and Japan to later emerging economies such as China, Taiwan, and South Korea. Recall that our index captures both quality and quantity increases in export production, implying from our regression results that both a shift in manufacturing focus towards this sector, as well as investments in higher level product lines within the sector can lead to economic growth.

The possibility does exist that our measure of sector sophistication may be skewed by the inclusion of observations from countries with incomplete data over the entire panel. As mentioned in the previous chapter, Hausmann et al. (2007) suggest that an unbiased estimate for product sophistication and thus overall country sophistication requires using only countries with a consistent set of observations, particularly since those countries missing observations likely come from the lower end of the development spectrum. Additional regressions have been computed using only such countries and are found in Appendix A. However, one should note that the effects of this change are not only in the countries included in the regressions, but also in how the product sophistication scores are constructed. The results also show the low-tech sector to be important, but not at the same level of robustness.

Our original model purports the use of exports in the construction of our sophistication variables because exports should represent the most productive industries in any economy. However, imports also represent special characteristics in an economy. They denote those goods which a country does not have a comparative advantage in producing and/or which it requires as inputs for its own manufacturing purposes. Using the same reasoning as in our previous discussion the imports of wealthier countries then, should represent both those products in which low cost competition quickly erodes profitability and those that are essential in the manufacture of products that require such a high level set of skills that countries with low labor costs cannot easily imitate their production. Reconstructing our dataset weighting countries' sophistication by imports rather than exports and again running growth regressions we find that importing the same goods that rich countries import has the most robust and significant impact on growth in the high-tech sector. This suggests that a country's imports may serve as a good indicator of its economic growth potential. Table 3.5 shows our regression results using imports.

Table 3.5 – Import sophistication by sector and growth

	(1) Pooled-5	(2) FE-5	(3) Pooled-10	(4) FE-10
VARIABLES	gdpg5a	gdpg5a	gdpg10a	gdpg10a
lnhc15	0.0116***	-0.00602	0.00915***	-0.00907*
	(0.00270)	(0.00564)	(0.00256)	(0.00500)
lngdpc	-0.00644**	-0.0294***	-0.00587***	-0.0249***
	(0.00267)	(0.00797)	(0.00186)	(0.00471)
lnPexpya	0.00690*	0.00299	0.00680***	0.000863
	(0.00363)	(0.00418)	(0.00215)	(0.00262)
lnRBexpya	0.000587	-0.00236	0.0103***	0.00893*
	(0.00705)	(0.00873)	(0.00396)	(0.00468)
lnLTexpya	-0.000918	0.00107	-9.43e-05	0.00116
	(0.00551)	(0.00566)	(0.00257)	(0.00333)
lnMTexpya	-0.00671	-0.00301	-0.00194	-0.00236
	(0.00436)	(0.00626)	(0.00479)	(0.00585)
lnHTexpya	0.00883*	0.00896**	0.00717***	0.00659**
	(0.00535)	(0.00411)	(0.00239)	(0.00321)
Constant	0.0303	0.235	-0.0738	0.143*
	(0.128)	(0.172)	(0.0638)	(0.0847)
Observations	852	852	473	473
R-squared	0.171	0.165	0.208	0.243
Countries		110		109

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.6 – Export sector sophistication and growth, using import PRODY

	(1) Pooled-5	(2) FE-5	(3) Pooled-10	(4) FE-10
VARIABLES	gdpg5a	gdpg5a	gdpg10a	gdpg10
lnhc15	0.00893***	-0.0144**	0.00804***	-0.0173***
	(0.00293)	(0.00673)	(0.00265)	(0.00579)
lngdpc	-0.00550*	-0.0123	-0.00651***	-0.0203***
	(0.00324)	(0.00916)	(0.00190)	(0.00456)
lnPexpya	-0.000680	0.00344	-0.00134	-0.000238
	(0.00206)	(0.00431)	(0.00136)	(0.00265)
lnRBexpya	0.00152	0.00189	0.00207	0.000526
	(0.00171)	(0.00322)	(0.00147)	(0.00259)
lnLTexpya	0.00533***	0.00481**	0.00395***	0.00279*
	(0.00184)	(0.00194)	(0.000922)	(0.00148)
lnMTexpya	-0.00262	-0.00124	-0.000416	0.00112
	(0.00248)	(0.00236)	(0.00119)	(0.00179)
lnHTexpya	0.00245*	0.00240*	0.00161	0.00137
	(0.00139)	(0.00145)	(0.000989)	(0.00129)
Constant	.0461	0.0883	0.0526**	0.194***
	(0.0417)	(0.112)	(0.0228)	(0.0534)
Observations	730	730	413	413
R-squared	0.209	0.186	0.260	0.304
Number of ecode		107		106

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

However, developing countries in particular may also be interested in the types of goods imported by wealthy countries, merely for the sake of ensuring greater demand by countries most able to afford their goods. Focusing on increasing the production of those products desired by the wealthiest countries could then also lead to economic growth. In order to analyze this possibility we have also reconstructed our sophistication index, by first ranking products by the wealth of the countries that import them. Thus in Table 3.6, we create our PRODY variable based on imports. We then use these PRODY values to rank what a country exports in the same manner used previously and regress this new export sophistication variable against economic growth. This regression shows that exporting goods in the low-tech sector, which wealthy countries import has a robust and significant relationship with economic growth, of nearly the same magnitude as our original sophistication-growth relationship. Though this is analysis is preliminary it suggests that our original theoretical model may need some modifications. Further research should investigate whether it is indeed the “cost discovery” process driving the relationship between low-tech sector sophistication and growth or the fact that low-tech sector products have a large import market in wealthier countries.

Our disaggregation of the original EXPY variable into a sector-level sophistication index highlights a number of important findings. Though motivated by the anomalous behavior of some primary and resource producing countries, our estimations suggest that, at least in general, increasing the sophistication of products in those sectors has little impact on economic growth. Instead, the two extremes of the manufacturing sector, the low and high-tech product categories have the most robust and significant relationship with per capita GDP increases. However, only the wealthiest subset of countries benefit from increasing their high-tech sector sophistication while increases in the sophistication of the low-tech sector have a positive and significant impact on growth in countries with varying income levels. Therefore, while not proven necessary for economic growth, establishing industrial capabilities in the low-tech sector clearly involves some process that generates a dynamic effect on economic growth. Further analysis shows that the wealth level of the countries that import these products may also be a determining factor in their ability to stimulate growth.

CHAPTER IV

I. Conclusion

The great inequality in per capita wealth that exists throughout the world today inspires research aimed at understanding the drivers of economic growth. This study has attempted to extend previous research on the relationship between product sophistication and increases in GDP/capita using a panel data-set covering 39 years and over 100 countries. Drawing on development and growth literature regarding the importance of technology spillovers and the necessity of uncovering the productivity of various industries through trials and failures, we have established a motive for examining how the types of products that a country exports affect its growth. We then re-examined previous studies on this topic, validated their results, and through analyzing those results inspired the need for an investigation into the role that specific sectors play in this process of export sophistication led growth.

In "What you export matters," Hausmann et al. (2007) developed a theoretical model based on the process of cost discovery in new industries. This model generated the idea for a variable they called EXPY, which reflects the overall productivity level of a country's productive sectors. By using exports as a proxy for these productive sectors, this variable ranks a country's level of productivity or sophistication by assigning a value to the goods in its export basket based on the wealth of all the countries that export those goods. We have recreated this variable using the same dataset and over 100 additional observations and after running a number of regressions using various methods of construction for the product and country sophistication indices, discovered the same positive, robustly significant relationship between a country's product sophistication and its economic growth. However, examining a number of special countries, both in terms of the types of products that they produce and the speed with which they have developed in recent years, we discovered that countries with an export focus in primary and resource based products received varying sophistication scores, and some had very high levels of growth. This prompted us to investigate if this relationship between sophistication and growth reflects merely a move from primary and resource-based production to the development of highly technical industries or if the sophistication of products within a particular sector also benefits overall growth.

In order to complete this analysis we created new sophistication variables, disaggregated into five sectors. The rubric for the classification of products into different sectors came from a paper by Sanjaya Lall that attempts to reflect the innovation and technological skills necessary for the production of a range of different goods. In his paper he discusses five different categories; primary products, resource-based products, and low, medium, and high-tech manufactures. Using the same PRODY product sophistication index developed in our examination of Hausmann et al. (2007) we generated each country's sector sophistication level by summing product sophistication scores by sector, which we then weighted by the percentage of overall trade represented by each product.

Using these newly created disaggregated sector sophistication variables we examined the product and country sophistication indices. The most sophisticated products in the primary category seemed to be driven somewhat artificially by being produced by only a small handful of wealthy countries. However, in the higher level sectors clear distinctions could be made between the top and bottom ranked products based on the types of processes their production likely involves. Additional analysis of the validity of these rankings could be the study of future research on industrial processes.

Investigating the countries with the highest sophistication scores in each sector it became evident that a high ranking involves both a quantity and quality component. In order for a country to increase its sector sophistication score it either must produce more of the products that wealthier countries produce in that sector, or increase its concentration on products from that category among its overall export basket. Attempts to disentangle these separate factors revealed disconcerting rankings and the theoretical underpinnings of our investigation suggest that the growth benefits from increased product sophistication may also be enhanced by a "quantity" component. Thus, our regression analysis took place within the framework of both sector sophistication and concentration. We also re-examined our special group of countries and their sector sophistication scores, noting an obvious step-wise pattern in the sophistication of progressive sectors.

Finally, we examined the relationship between these sector sophistication variables and economic growth. We immediately discovered a robust and significant effect from the low-tech sector. Further analysis confirmed that sophistication within the high-tech sector benefitted only the wealthiest countries in the sample, while the low-tech sector seemed to provide a positive contribution to growth for all countries outside this wealthiest class. The primary, resource-based, and medium-tech sectors, however, never appeared as a significant determinant of economic growth in any of our various model specifications. Additional regressions using only those countries for which we have a complete set of observations confirmed our findings in the low-tech sector. Through recreating our product and sector sophistication variables using imports, we found that importing the same goods as wealthier countries also has a positive impact on growth, but only in the high-tech sector. As concluding analysis, we created a product sophistication score of imports with a country sophistication score of exports, thus ranking each country by the wealth of the nations that import its goods. Growth regressions revealed that, at least in the low-tech sector, exporting more of the goods that wealthy countries import also increases economic growth.

Thus, this study has confirmed that the composition of a country's trade basket has an impact on its level of economic growth and it has identified two particular sectors that play important roles in producing this economic growth. However, it has also shown that a country's level of wealth does affect the level of product sophistication which it can successfully achieve. Further research is needed on the correlation between our products' sophistication ranks and the productive processes involved their production. In addition, preliminary analysis on an import sophistication variable has inspired investigation into how large a role import markets play in determining the growth benefits associated with increased production in more sophisticated industries.

APPENDIX A

Table A.1 – Countries with a full set of observations

Countries		
Algeria	Greece	Norway
Argentina	Guatemala	Oman
Australia	Guinea	Pakistan
Austria	Honduras	Panama
Barbados	Hong Kong	Paraguay
Belgium	Iceland	Peru
Benin	India	Philippines
Bolivia	Indonesia	Portugal
Brazil	Iran	Romania
Burkina Faso	Iraq	Rwanda
Burundi	Ireland	Senegal
Cameroon	Israel	Singapore
Canada	Italy	South Africa
Chad	Jamaica	Spain
Chile	Japan	Sri Lanka
China	Jordan	Sweden
Colombia	Kenya	Switzerland
Congo, Republic of	Korea, Republic of	Syria
Costa Rica	Madagascar	Taiwan
Cote d`Ivoire	Malawi	Tanzania
Denmark	Malaysia	Thailand
Dominican Republic	Mali	Togo
Ecuador	Mauritius	Trinidad &Tobago
Egypt	Mexico	Tunisia
El Salvador	Morocco	Turkey
Equatorial Guinea	Mozambique	Uganda
Ethiopia	Nepal	United Kingdom
Finland	Netherlands	United States
France	New Zealand	Uruguay
Gabon	Nicaragua	Venezuela
Gambia, The	Niger	Zambia
Ghana	Nigeria	Zimbabwe

Table A.2 – Countries with less than a full set of observations

Countries, Number of years of available data					
Seychelles	1	Lebanon	10	Oman	31
Guyana	1	Slovak Republic	10	Sierra Leone	31
Libya	1	Yemen	10	Mauritania	31
Angola	1	Albania	11	Korea, Dem. Rep.	31
Armenia	6	Russia	11	Laos	31
Belarus	6	Vietnam	12	Bahamas	31
Azerbaijan	7	Germany	12	Cambodia	31
Lithuania	8	Djibouti	22	Central African Republic	31
Macedonia	8	Bangladesh	29	Congo, Dem. Rep.	31
Kyrgyzstan	8	Cyprus	31	Bahrain	31
Tajikistan	8	Sudan	31	Cuba	31
Czech Republic	8	Macao	31	Poland	31
Ukraine	8	Liberia	31	Hungary	31
Turkmenistan	8	Mongolia	31	Haiti	31
Kazakhstan	8	Belize	31	Qatar	31
Latvia	8	Kuwait	31	Fiji	31
Georgia	9	Afghanistan	31	Saudi Arabia	31
Croatia	9	Netherlands Antilles	31	Suriname	31
Slovenia	9	Malta	31	Iraq	31
Uzbekistan	9	United Arab Emirates	31	Malawi	38
Bosnia and Herzegovina	9	Samoa	31	Zimbabwe	38
Estonia	9	Papua New Guinea	31	Rwanda	38
Moldova	9	Bermuda	31		
Bulgaria	10	Somalia	31	Average Years	20.9

Table A.3 Export sophistication and growth, full observation countries only

	(1) Pooled-5	(2) FE-5	(3) Pooled-10	(4) FE-10
VARIABLES	gdpg5a	gdpg5a	gdpg10a	gdpg10a
lnexpya	0.0282***	0.0168*	0.0228***	0.00270
	(0.00541)	(0.00867)	(0.00523)	(0.00691)
lnhc15	0.00945***	-0.00509	0.00738***	-0.00981
	(0.00243)	(0.00545)	(0.00249)	(0.00606)
lngdpc	-0.0125***	-0.0232***	-0.00953***	-0.0197***
	(0.00250)	(0.00569)	(0.00254)	(0.00472)
Constant	-0.115***	0.0843	-0.0932***	0.178**
	(0.0341)	(0.0759)	(0.0329)	(0.0736)
Observations	731	731	405	405
R-squared	0.181	0.171	0.185	0.221
Countries		84		84

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A.4 – Highest/Lowest products by PRODYA, Primary

Resource Based Top-Bottom Products	**PRODYA**
SISAL & OTHER FIBRES OF AGAVE FAMILY	996.8558
JUTE & OTHER TEXTILE BAST FIBRES,NES,RAW/PROCESSED	1344.527
GROUNDNUT (PEANUT) OIL	1399.927
TIN ORES AND CONCENTRATES	1890.289
WAXES OF ANIMAL OR VEGETABLE ORIGIN	1900.643
SYNTHETIC ORGANIC DYESTUFFS	15905.93
BACON, HAM & OTHER DRIED,SALTED,SMOKED MEAT OF SWI.	15938.57
SYNTH.ORGANIC LUMINOPHORES;OPTIC.BLEACHING AGENTS	16204.41
NITROGEN-FUNCTION COMPOUNDS	16236.07
PAPER & PAPERBOARD,IMPREGNAT.COAT.SURFACE-COLOURE	17250.6

Table A.5 – Highest/Lowest products by PRODYA, Low-Tech

Low-Tech Top-Bottom Products	**PRODYA**
FABRICS,WOVEN,OF JUTE OR OF OTHER TEXTILE BAST FIB	1578.354
CARPETS,CARPETING AND RUGS,KNOTTED	1896.866
SACKS AND BAGS,OF TEXTILE MATERIALS	2642.696
KELEM,SCHUMACKS AND KARAMANIE RUGS AND THE LIKE	2643.926
LEATHER OF OTHER HIDES OR SKINS	2826.17
KNITTED/CROCHETED FABRICS ELASTIC OR RUBBERIZED	14610.52
CARPETS,RUGS ETC.OF MAN-MADE TEXTILE MATERIALS NES	14688.21
ART.OF ELECTRIC LIGHTING OF MATERIALS OF DIV.58	15541
YARN OF REGENERATED FIBRES,PUT UP FOR RETAIL SALE	15747.96
ORTHOPAEDIC APPLIANCES,SURGICAL BELTS AND THE LIKE	16134.39

Table A.6 – Highest/Lowest products by PRODYA, Med-Tech

Medium-Tech Top-Bottom Products	**PRODYA**
PIG IRON,CAST IRON AND SPIEGELEISEN,IN PIGS,BLOCKS	3694.512
MINERAL OR CHEMICAL FERTILIZERS,PHOSPHATIC	4563.651
MINERAL OR CHEMICAL FERTILIZERS.POTASSIC	4894.989
BLOOMS,BILLETS,SLABS & SHEET BARS OF IRON OR STEEL	5313.213
SHIPS,BOATS AND OTHER VESSELS FOR BREAKING UP	5870.671
COPOLYMERS OF VINYL CHLORIDE AND VINYL ACETATE	18060.76
EPOXIDE RESINS	18539.8
ANTI-KNOCK PREPARATIONS,OXIDATION INHIBITORS ETC.	18641.68
ROTARY PUMPS,OTHER THAN 742.81	18938.97
BOOKBINDING MACHINERY AND PARTS	19031.01

Table A.7 – Highest/Lowest products by PRODYA, High-Tech

High-Tech Top-Bottom Products	**PRODYA**
FISSILE CHEMICAL ELEMENTS AND ISOTOPES	4856.107
ELECTRICAL MACHINERY AND APPARATUS,N.E.S.	7726.411
DIODES,TRANSISTORS AND SIM.SEMI-CONDUCTOR DEV.	8637.151
TELEVISION RECEIVERS,MONOCHROME	8684.689
TYPEWRITTERS;CHEQUE-WRITTING MACHINES	8822.92
PHOTOGRAPHIC APPARATUS AND EQUIPMENT,N.E.S.	17276.33
OTHER POWER GENERATING MACHINERY AND PARTS	17364.34
INSTR.& APP.FOR PHYSICAL OR CHEMICAL ANALYSIS	17988.54
COMPLETE DIGITAL CENTRAL PROCESSING UNITS	18061.49
AIRCRAFT NOT EXCEEDING AN UNLADEN WEIGHT, 15000 KG	18250.7

Table A.8 - Sector sophistication and growth, by HDI rank, group 1

	(1)	(2)	(3)	(4)
	Pooled-5	FE-5	Pooled-10	Fixed-10
VARIABLES	gdpg5a	gdpg5a	gdpg10a	gdpg10a
lnhc15	0.00758	0.00202	0.00995*	-0.00394
	(0.00607)	(0.0135)	(0.00543)	(0.0120)
lngdpc	-0.0139***	-0.0309***	-0.0159***	-0.0308***
	(0.00369)	(0.0101)	(0.00327)	(0.00773)
lnPexpya	-0.00304**	-0.00140	-0.00273*	-0.000649
	(0.00140)	(0.00385)	(0.00145)	(0.00399)
lnRBexpya	0.00124	-0.00101	0.00282	-0.00733
	(0.00232)	(0.00498)	(0.00217)	(0.00566)
lnLTexpya	0.00386**	0.00452	0.00381**	0.00399
	(0.00166)	(0.00311)	(0.00165)	(0.00297)
lnMTexpya	-0.000217	-0.00195	9.29e-05	-0.000928
	(0.00213)	(0.00373)	(0.00241)	(0.00445)
lnHTexpya	0.000239	-7.97e-05	-0.000396	-0.00166
	(0.00171)	(0.00226)	(0.00223)	(0.00264)
Constant	0.142***	0.312***	0.141***	0.366***
	(0.0308)	(0.109)	(0.0299)	(0.0930)
Observations	402	402	225	225
R-squared	0.270	0.257	0.326	0.375
Countries		53		52

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A.9 – Sector sophistication and growth, by income group, Group 1

	(1) Pooled-5	(2) FE-5	(3) Pooled-10	(4) FE-10
VARIABLES	gdpg5a	gdpg5a	gdpg10a	gdpg10a
lnhc15	-0.00556	-0.0200	-0.00257	-0.0144
	(0.00792)	(0.0162)	(0.00699)	(0.0150)
lngdpc	-0.0306***	-0.0404**	-0.0305***	-0.0316***
	(0.00987)	(0.0160)	(0.00729)	(0.0108)
lnPexpya	-0.00141	3.46e-05	-0.000105	0.00278
	(0.00156)	(0.00595)	(0.00131)	(0.00469)
lnRBexpya	-0.00534*	0.00117	-0.00281	0.00174
	(0.00292)	(0.00585)	(0.00273)	(0.00619)
lnLTexpya	-0.00350	-0.00238	-0.000299	0.00144
	(0.00304)	(0.00409)	(0.00263)	(0.00456)
lnMTexpya	-0.00379	-0.00781	-0.00372	-0.00589
	(0.00345)	(0.00634)	(0.00303)	(0.00550)
lnHTexpya	0.00583***	0.0140***	0.00521**	0.0100***
	(0.00213)	(0.00317)	(0.00220)	(0.00265)
Constant	0.405***	0.435**	0.345***	0.299***
	(0.0900)	(0.182)	(0.0611)	(0.107)
Observations	173	173	97	97
R-squared	0.519	0.499	0.633	0.608
Countries		20		20

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A.10 – Sector sophistication and growth, by income groups, Group 2

	(1)	(2)	(3)	(4)
	Pooled-5	FE-5	Pooled-10	FE-10
VARIABLES	gdpg5a	gdpg5a	gdpg10a	gdpg10a
lnhc15	-0.00276	-0.00602	-0.000169	-0.0141
	(0.00608)	(0.0129)	(0.00594)	(0.0135)
lngdpc	-0.0155***	-0.0221*	-0.0167***	-0.0300***
	(0.00408)	(0.0114)	(0.00358)	(0.00969)
lnPexpya	-0.00401**	-0.000155	-0.00374*	-0.000297
	(0.00184)	(0.00461)	(0.00192)	(0.00562)
lnRBexpya	0.000501	0.00494	-0.000210	-0.0122
	(0.00301)	(0.00668)	(0.00269)	(0.00740)
lnLTexpya	.00534***	0.00742**	0.00422**	0.00395
	(0.00197)	(0.00333)	(0.00211)	(0.00339)
lnMTexpya	0.00239	0.000108	0.00323	0.00519
	(0.00239)	(0.00436)	(0.00269)	(0.00492)
lnHTexpya	-0.00134	-0.000719	-0.00159	-0.00160
	(0.00185)	(0.00257)	(0.00251)	(0.00343)
Constant	0.161***	0.159	0.177***	0.365***
	(0.0452)	(0.128)	(0.0419)	(0.117)
Observations	260	260	145	145
R-squared	0.317	0.281	0.367	0.406
Countries		36		35

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A.11 – Sector sophistication and growth, by income groups, Group 3

	(1)	(2)	(3)	(4)
	Pooled-5	FE-5	Pooled-10	FE-10
VARIABLES	gdpg5a	gdpg5a	gdpg10a	gdpg10a
lnhc15	0.00897**	-0.0169	0.00583*	-0.0233**
	(0.00364)	(0.0114)	(0.00346)	(0.0107)
lngdpc	-0.00447	-0.00118	-0.00597	-0.0143**
	(0.00553)	(0.0138)	(0.00393)	(0.00556)
lnPexpya	0.00432	0.00319	0.00103	-0.00506
	(0.00420)	(0.00889)	(0.00272)	(0.00434)
lnRBexpya	0.00300	-0.000467	0.00384	0.00250
	(0.00249)	(0.00411)	(0.00271)	(0.00324)
lnLTexpya	0.00647**	0.00629*	0.00435**	0.00287
	(0.00266)	(0.00338)	(0.00171)	(0.00245)
lnMTexpya	-0.00473	-0.00276	-0.00145	0.000710
	(0.00386)	(0.00358)	(0.00187)	(0.00302)
lnHTexpya	0.00290	0.00250	0.00185	0.00144
	(0.00205)	(0.00232)	(0.00153)	(0.00177)
Constant	-0.00202	0.0103	0.0200	0.145**
	(0.0611)	(0.164)	(0.0335)	(0.0718)
Observations	297	297	171	171
R-squared	0.187	0.157	0.199	0.267
Countries		51		51

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A.12 - Sector sophistication and growth, consistent countries only

	(1)	(2)	(3)	(4)
	Pooled-5	FE-5	Pooled-10	FE-10
VARIABLES	gdpg5a	gdpg5a	gdpg10a	gdpg10a
lnhc15	0.00954***	-0.00743	0.00739***	-0.00997**
	(0.00251)	(0.00573)	(0.00254)	(0.00507)
lngdpc	-0.00896***	-0.0226***	-0.00773***	-0.0201***
	(0.00241)	(0.00596)	(0.00211)	(0.00519)
lnPexpya	-0.00192*	-0.00342	-0.00137	-0.00107
	(0.00113)	(0.00294)	(0.00131)	(0.00248)
lnRBexpya	0.00142	0.000330	0.00166	-0.00187
	(0.00180)	(0.00347)	(0.00153)	(0.00248)
lnLTexpya	0.00249**	0.00217	0.00209*	0.00119
	(0.00109)	(0.00137)	(0.00116)	(0.00160)
lnMTexpya	0.00136	0.00107	0.00218	0.00242
	(0.00129)	(0.00187)	(0.00138)	(0.00181)
lnHTexpya	0.00160*	0.00291**	0.00110	0.00155
	(0.000972)	(0.00137)	(0.000994)	(0.00124)
Constant	0.0794***	0.224***	0.0618***	0.204***
	(0.0199)	(0.0665)	(0.0198)	(0.0572)
Observations	711	711	398	398
R-squared	0.206	0.206	0.234	0.255
Countries		83		83

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

APPENDIX B

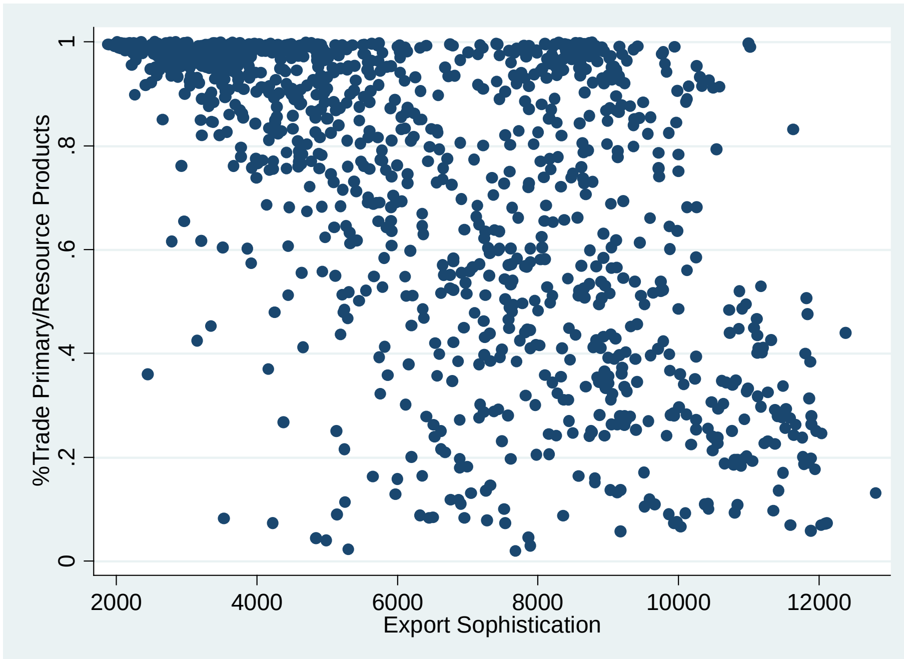


Figure B.1 - %Trade in primary/resource products and export sophistication

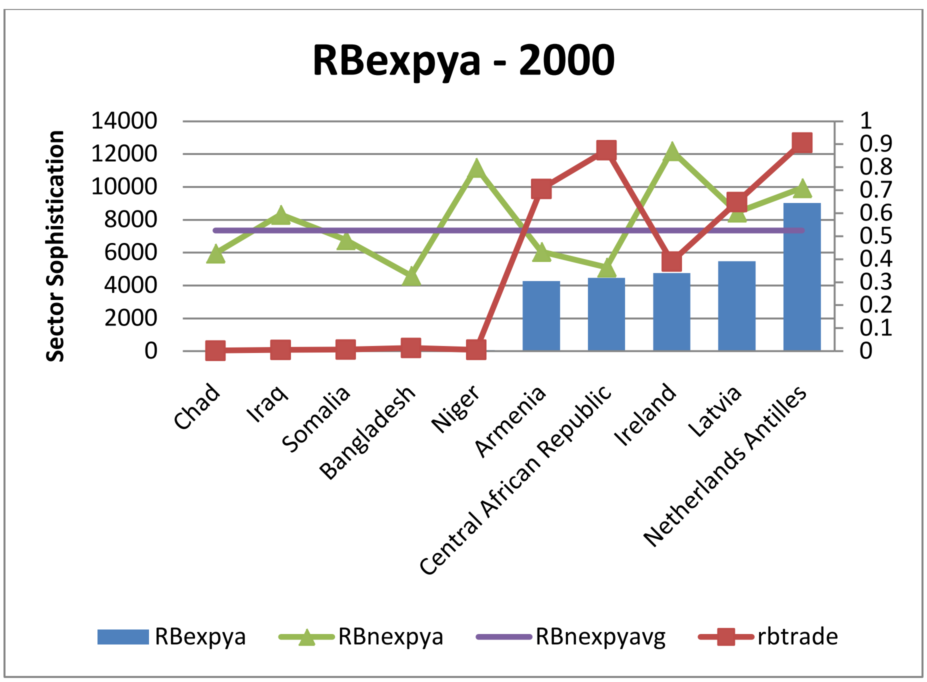


Figure B.2 – Highest/lowest ranked countries by Resource-Based Sector

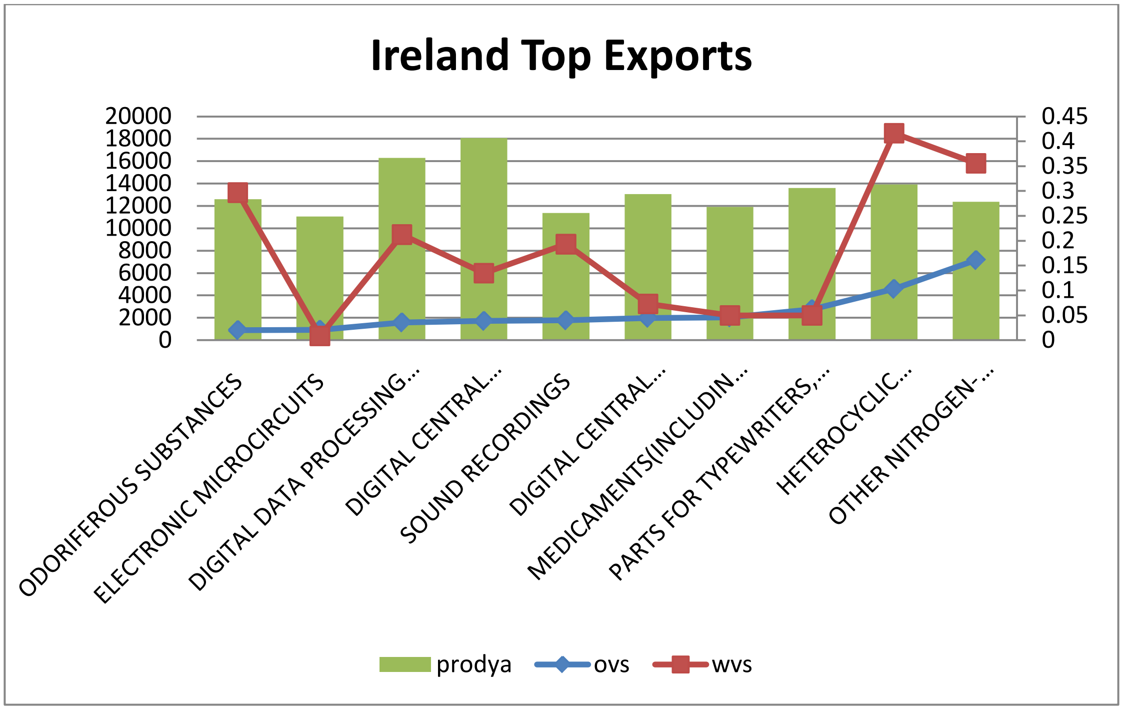


Figure B.3 – Top ten exports by value, Ireland, 2000

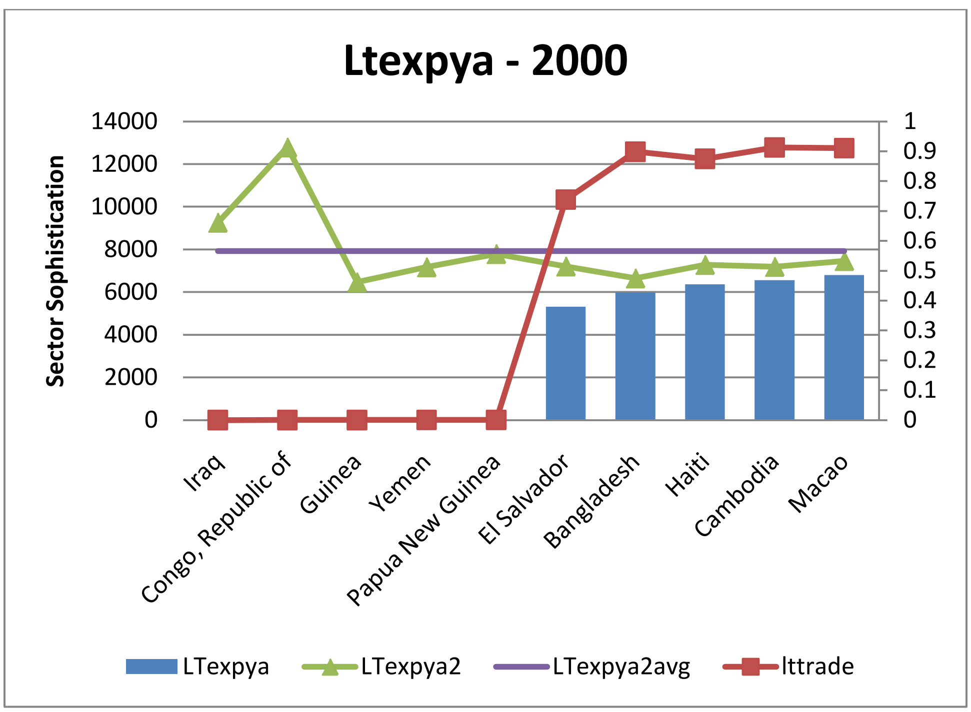


Figure B.4 – Highest/lowest ranked countries by Low-Tech Sector

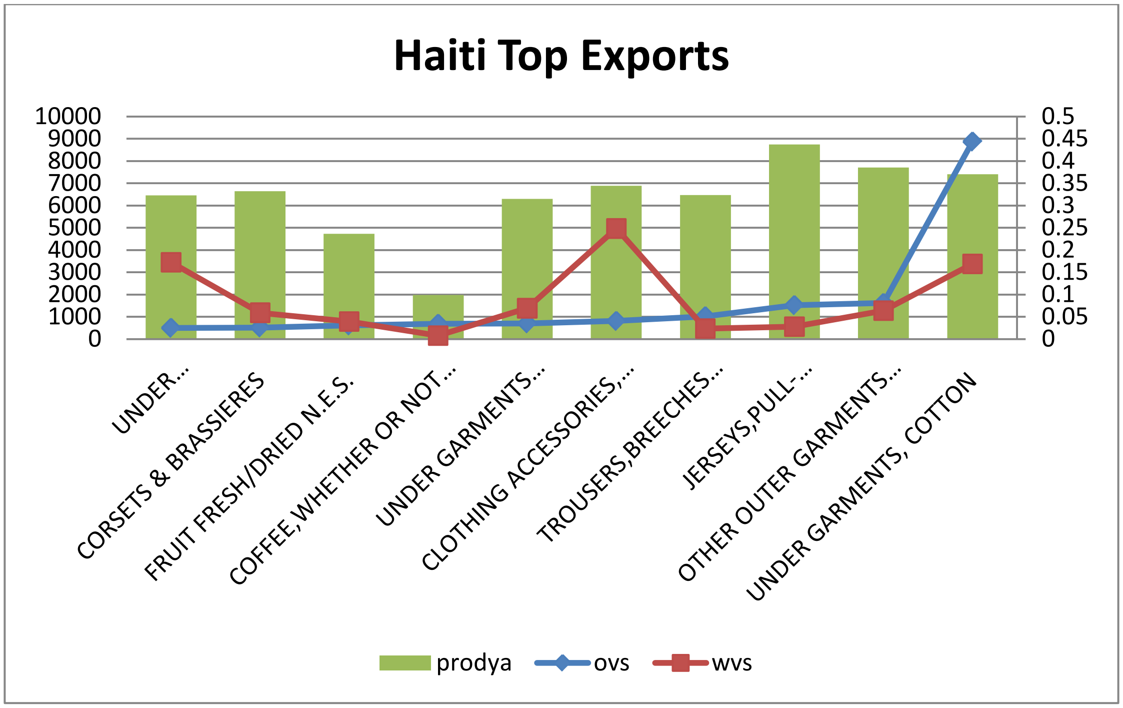


Figure B.5 – Top ten exports by value, Haiti, 2000

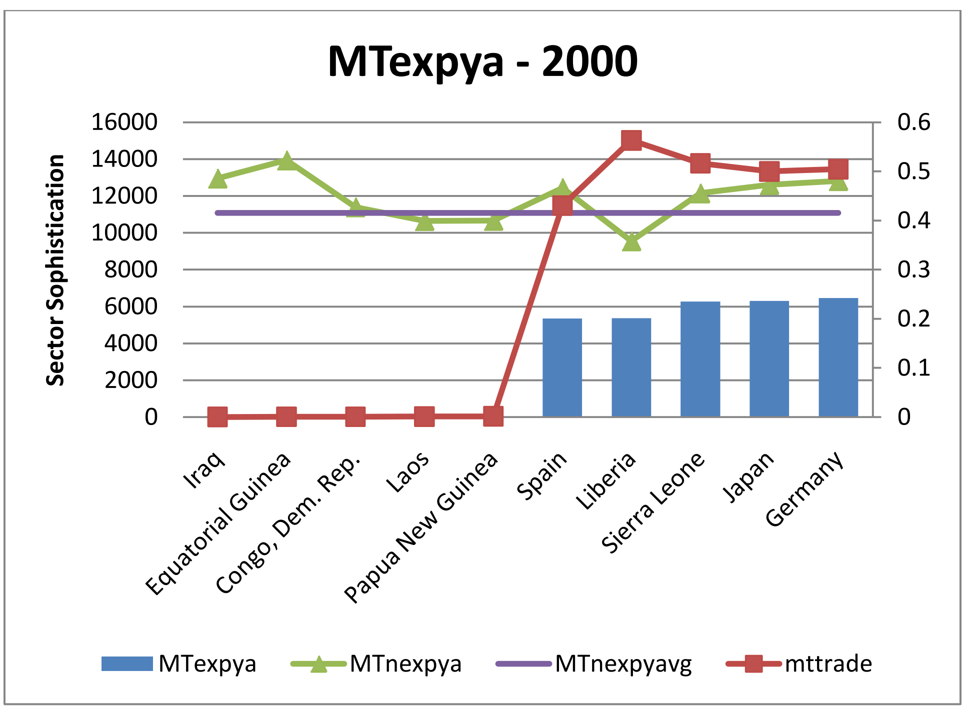


Figure B.6 – Highest/lowest ranked countries by Med-Tech Sector

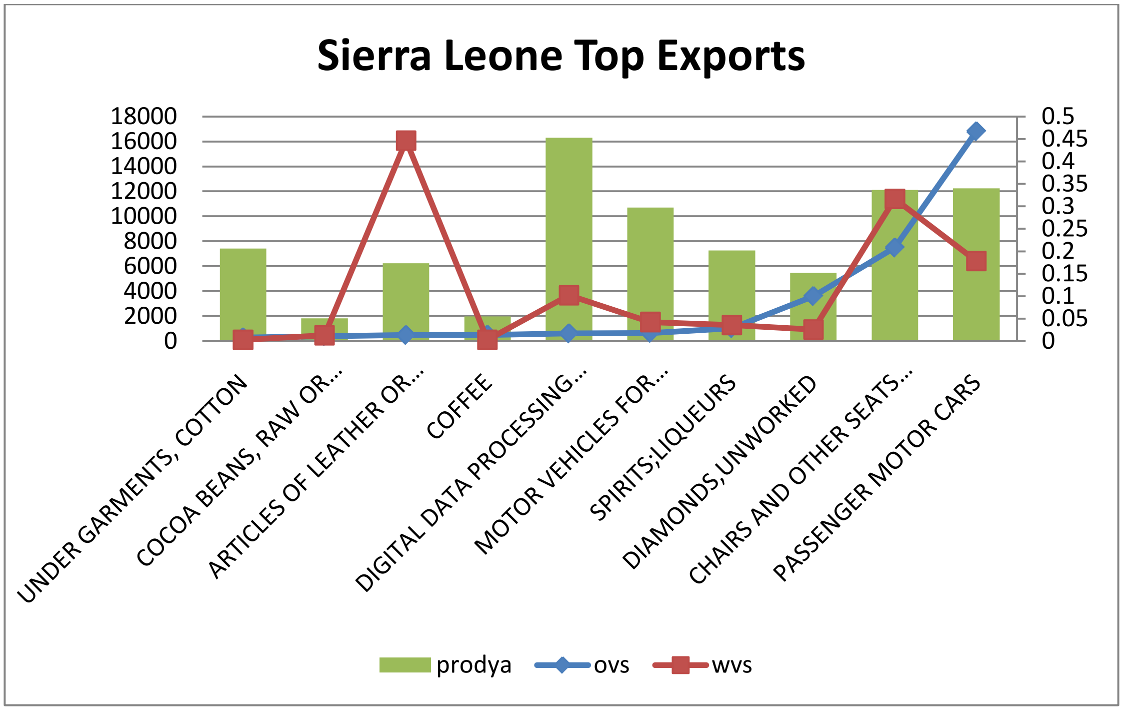


Figure B.7 – Top ten exports by value, Sierra Leone, 2000

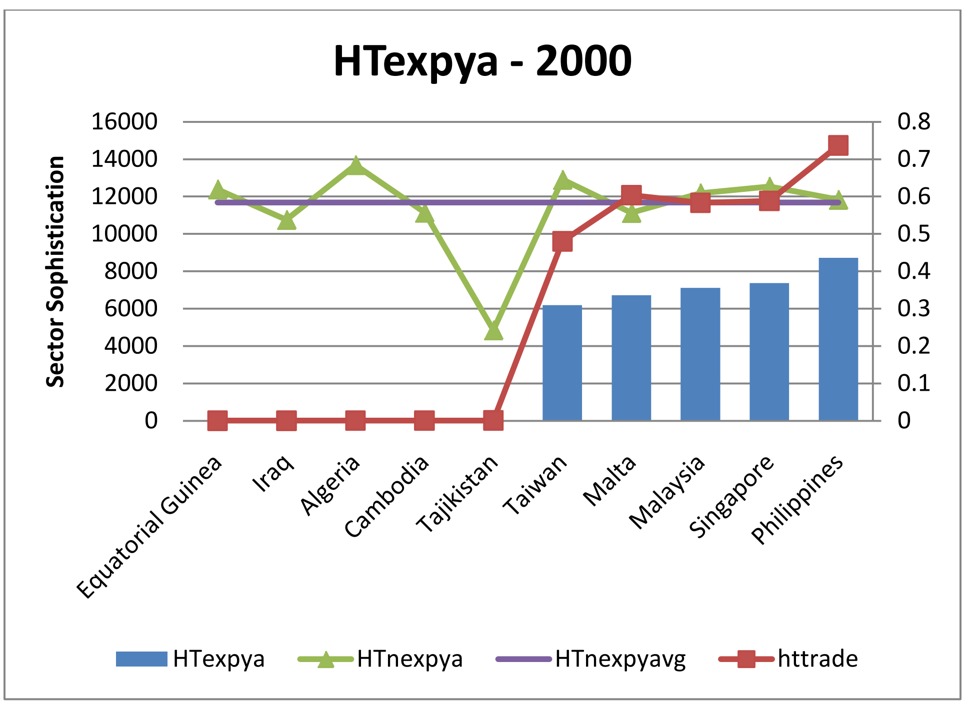


Figure B.8 – Highest/lowest ranked countries by High-Tech Sector

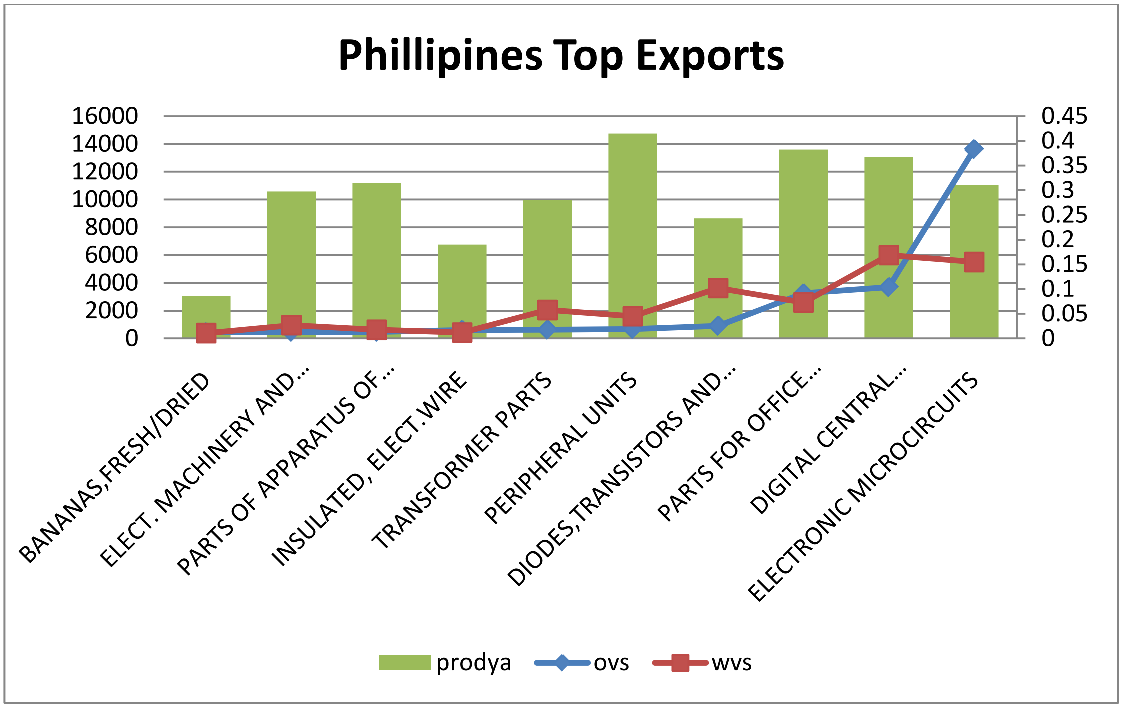


Figure B.9 – Top exports by value, Philippines, 2000

APPENDIX C

1) Tests for stationarity of variables

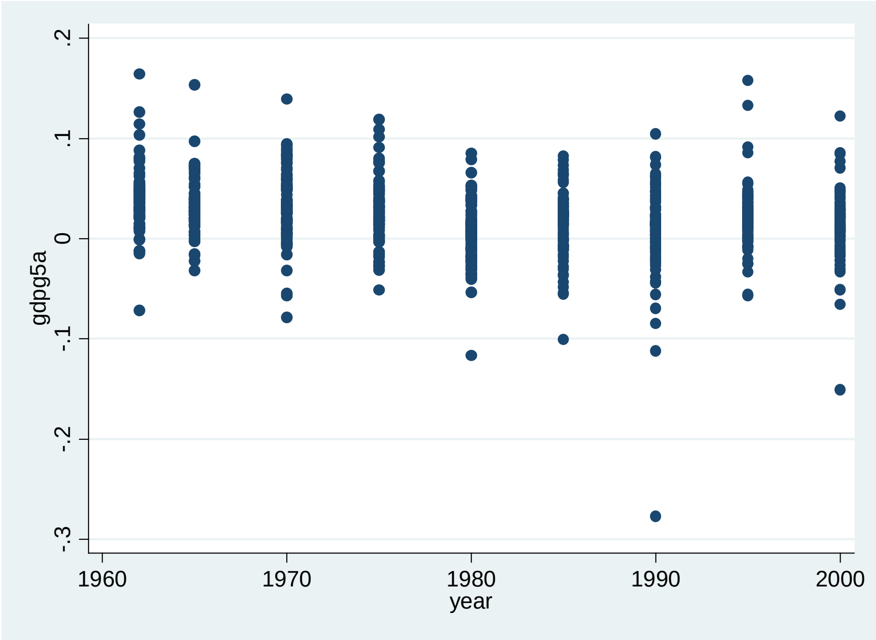


Figure C.1 – Average growth over time

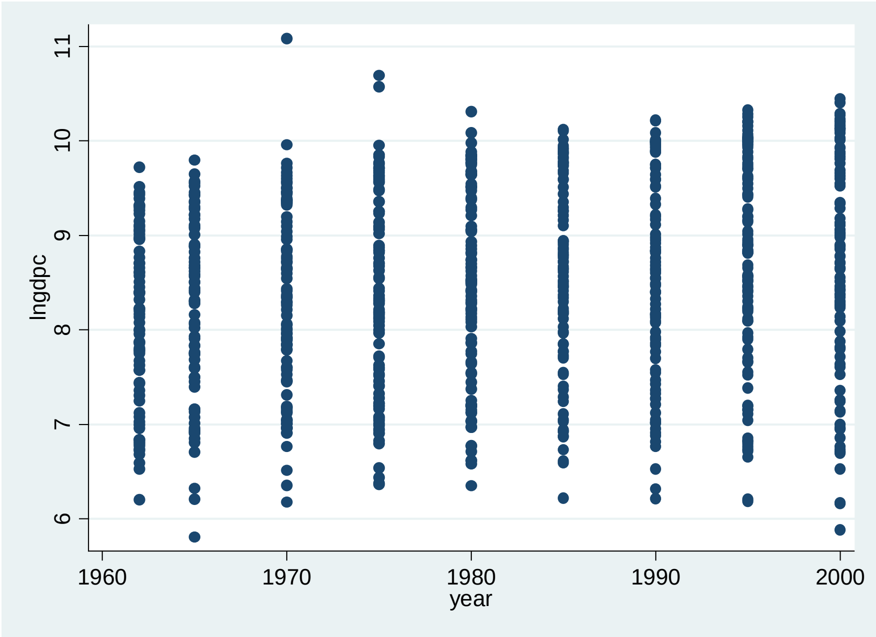


Figure C.2 – GDP/capita over time

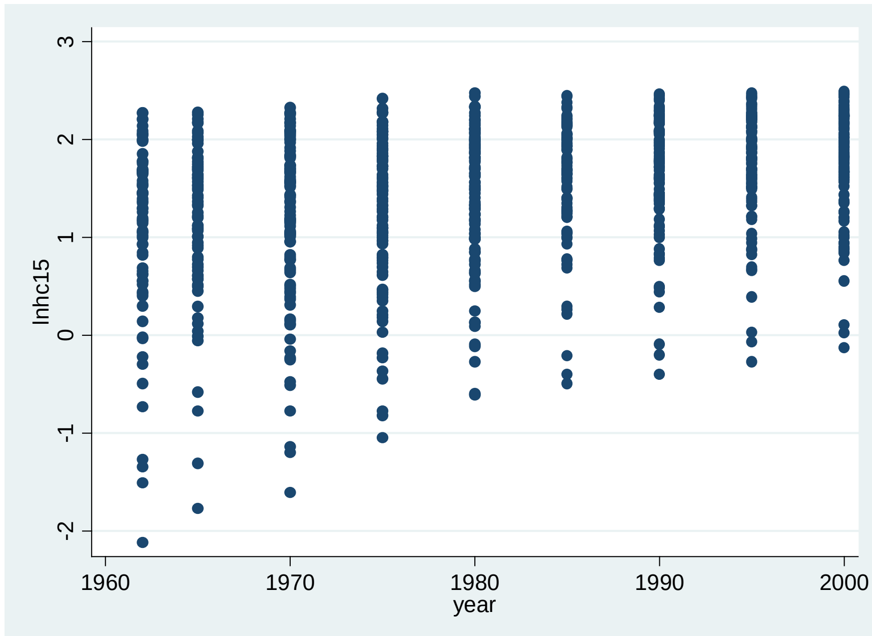


Figure C.3 – Human capital over time

Figure C.4 – Export sophistication over time

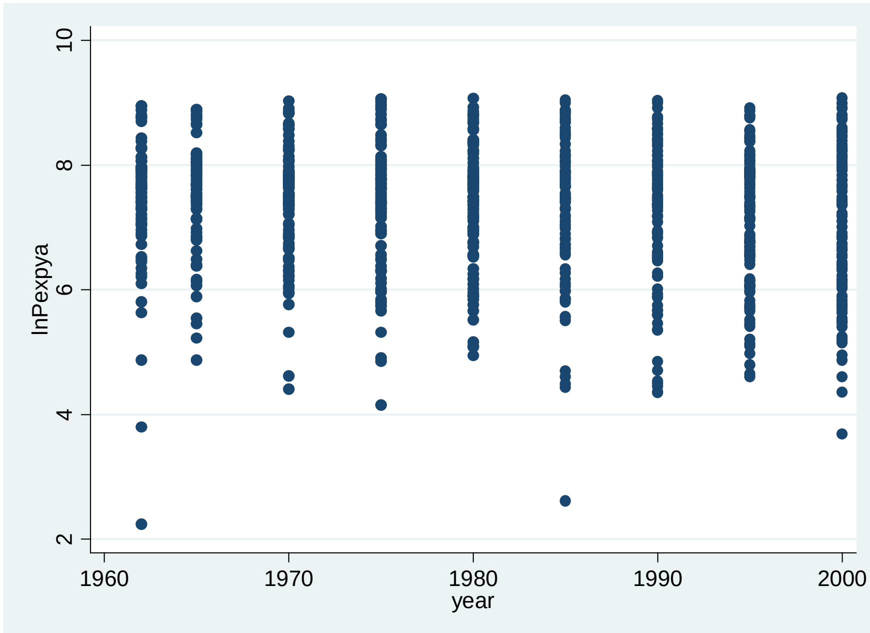


Figure C.5 – Primary sector sophistication over time

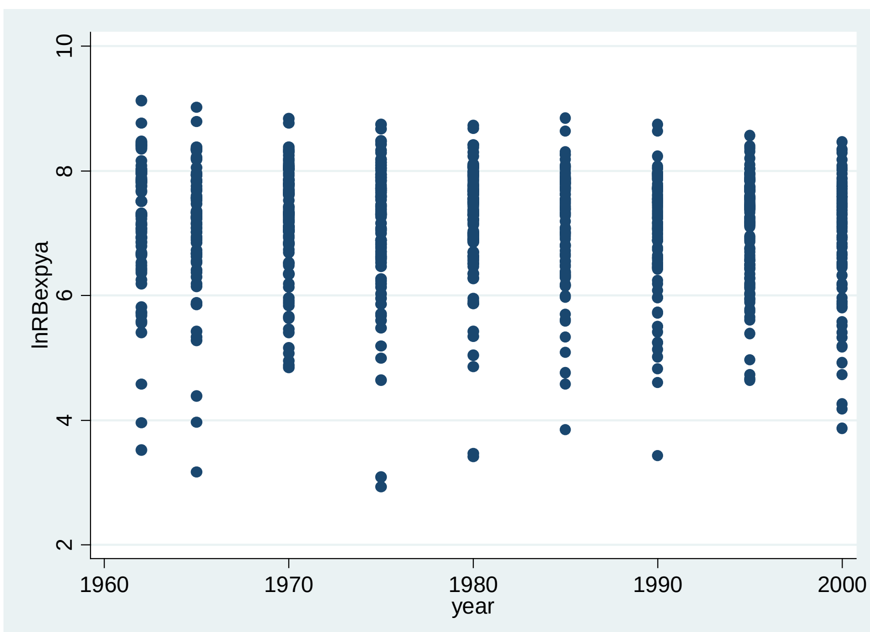


Figure C.6 - Resource based sector sophistication over time

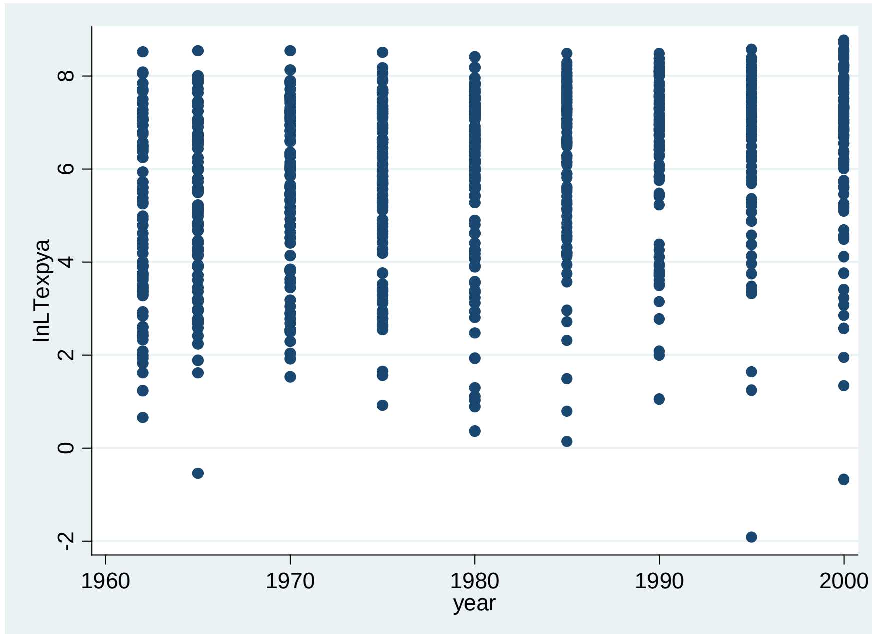


Figure C.7 – Low tech sector sophistication over time

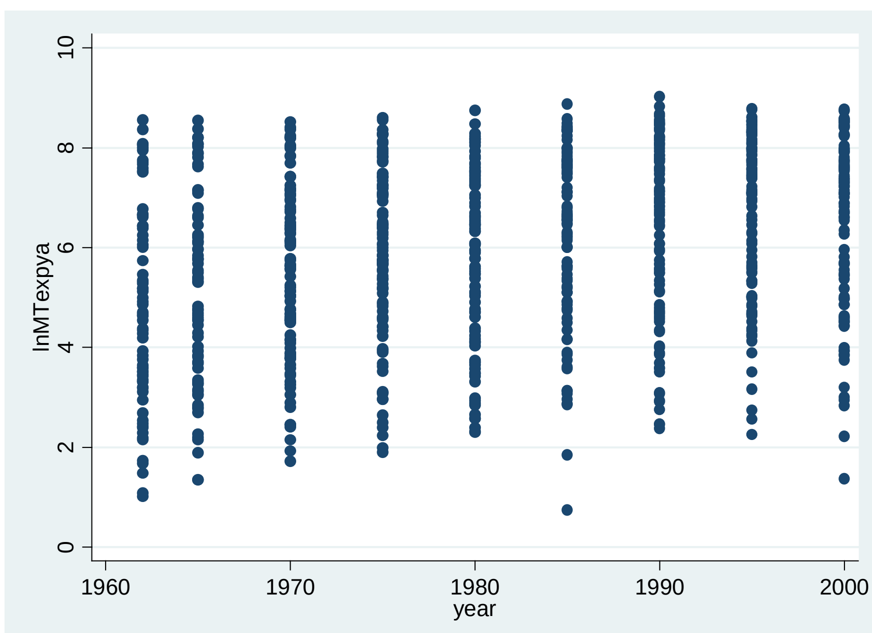


Figure C.8 – Medium tech sector sophistication over time

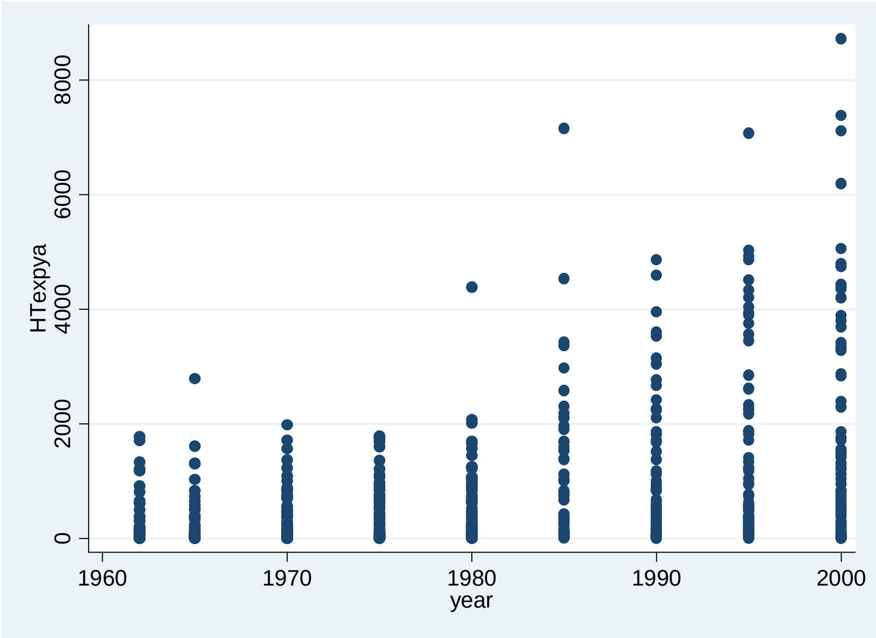


Figure C.9 – High tech sector sophistication over time

Analysis – Overall it appears that our data is stationary in all variables over time.

2) Test for multi-collinearity, aggregated model

Table C.1 – Variance inflation factors, aggregated expy model

Variable	VIF	1/VIF
lngdpc	3.42	0.29265
lnexpya	2.78	0.3591
lnhc15	2.4	0.41723
Mean VIF	2.87	

Analysis – Here we see that our variance inflation factors, which account for the amount of variation in each independent variable explained by the other independent variables, lies below 5 for each of our variables. This suggests that we have no problems with multi-collinearity. No correction is needed.

3) Test for heteroskedasticity, aggregated model

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
Ho: Constant variance
Variables: fitted values of gdpg5a

chi2(1) = 5.94
Prob > chi2 = 0.0148

Analysis – The Breusch-Pagan test computed using residual matrices gives a p-value of 0.0148. Therefore, we reject the null of homoskedasticity and perform our regressions using White's robust standard errors to ensure consistent estimators.

4) Test for normality, aggregated model

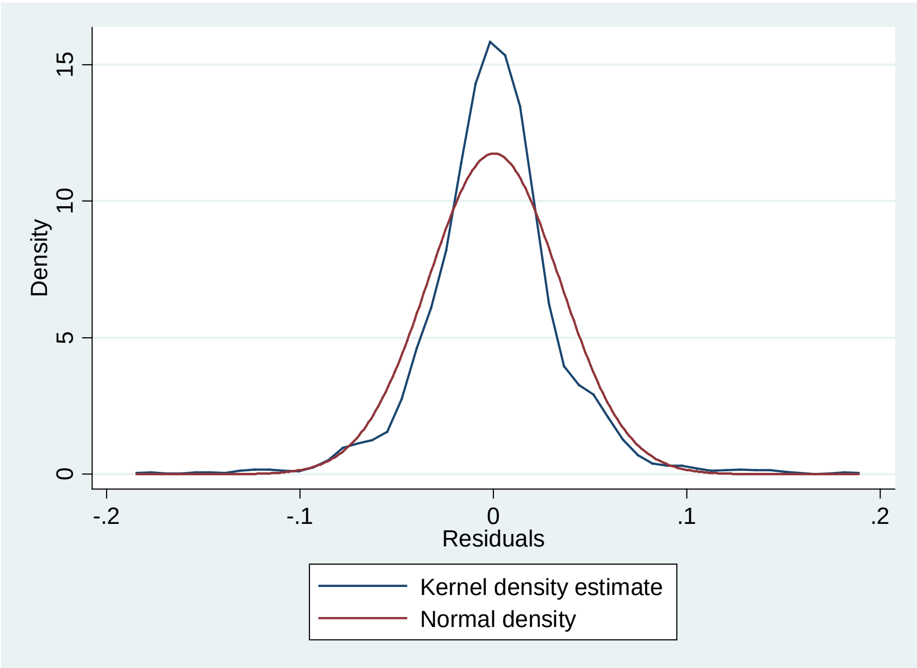


Figure C.10 – Residual density plot

Analysis-The graph above suggests that our residuals are not distributed perfectly normal. However, given our very large sample size, 858, we appeal to the central limit theorem, which assures us of the asymptotic normality of our estimators regardless of the normality of our residuals

5) Test for auto-correlation, aggregated model

Table C.2 – Lagged residuals regression, aggregated model

	(1)
VARIABLES	e_1
lnexpya	0.00300
	(0.00443)
lnhc15	0.00139
	(0.00246)
lngdpc	-0.00263
	(0.00210)
e_2	0.175***
	(0.0367)
e_3	0.101**
	(0.0420)
e_4	-0.0419
	(0.0511)
e_5	0.109**
	(0.0553)
e_6	-0.0969
	(0.0637)
e_7	-0.0599
	(0.0750)
e_8	0.0926
	(0.0975)
e_9	-0.0234
	(0.119)
Constant	-0.00599
	(0.0301)
Observations	858
R-squared	0.045

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Analysis – Using the Breusch-Godfrey test for autocorrelation we regress the residuals against all possible lags and the independent variables. Strong correlation suggests auto-correlation. Though we see that the first residual is significant, the test-statistic is R^2*T, where t is the number of periods(9), distributed Chi-2(p) where p is the number of lags(8). Thus, we have a test-statistic of (0.045*9)= 0.405 and critical value of 1.65. Conclusion: fail to reject null, no autocorrelation.

6) Test for normality, disaggregated model

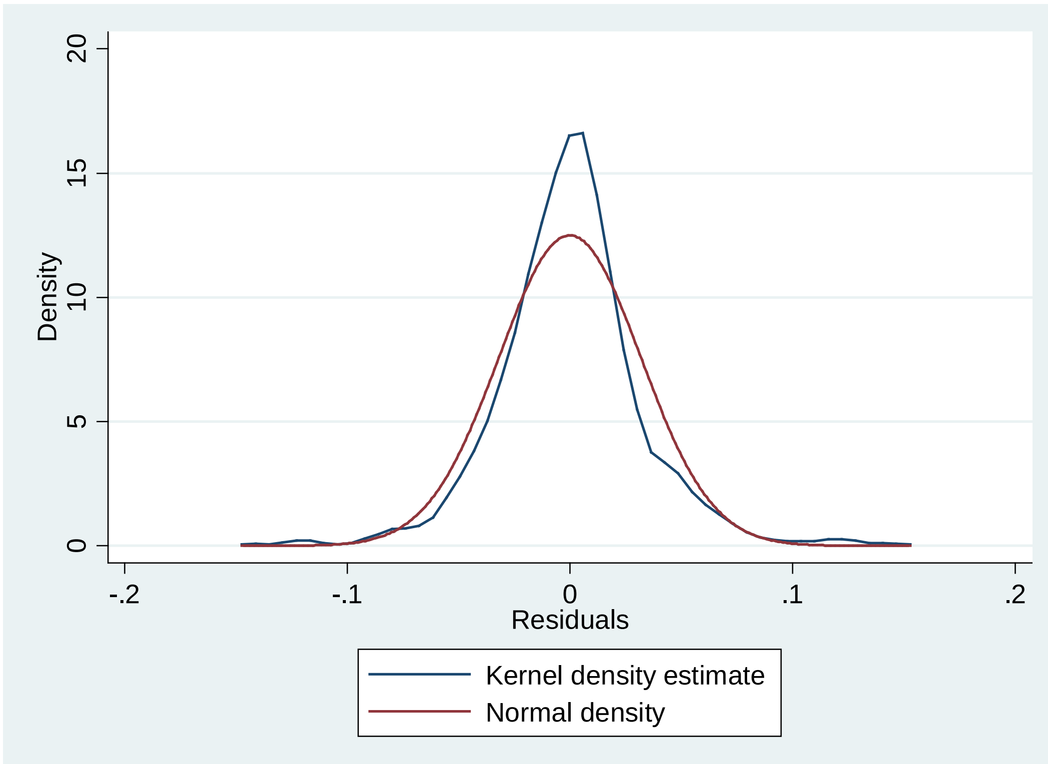


Figure C.11 – Residual density plot

Analysis-Though not appearing perfectly normal, we again appeal to the central limit theorem due to our 730 observations, which assures us of the asymptotic normality of our estimators regardless of the normality of our residuals.

7) Test for heteroskedasticity, disaggregated model

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
Ho: Constant variance
Variables: fitted values of gdpg5a

chi2(1) = 44.64
Prob > chi2 = 0.0000

Analysis – With a p-value of 0.0000 we reject the null of homoskedasticity and perform our regressions using White's robust standard errors to ensure consistent estimators.

8) Test for autocorrelation, disaggregated model

Table C.3 – Lagged residual regression, disaggregated model

	(1)
VARIABLES	e_1
lnhc15	-0.000666
	(0.00242)
lngdpc	3.40e-05
	(0.00185)
lnPexpya	-0.000214
	(0.00121)
lnRBexpya	4.49e-05
	(0.00139)
lnLTexpya	0.000102
	(0.000950)
lnMTexpya	0.000250
	(0.00119)
lnHTexpya	-0.000528
	(0.000983)
e_2	0.107***
	(0.0374)
e_3	0.123***
	(0.0405)
e_4	0.0666
	(0.0437)
e_5	0.0128
	(0.0511)
e_6	0.00561
	(0.0577)
e_7	-0.0194
	(0.0665)
e_8	0.122
	(0.0993)
e_9	0.0393
	(0.139)
Constant	0.00209
	(0.0172)
Observations	830
R-squared	0.033

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Analysis – Using the Breusch-Godfrey test for autocorrelation again the test-statistic is (0.033*9)= 0.297 and critical value of 1.65. Conclusion: fail to reject null, no autocorrelation.

9) Test for multi-collinearity, disaggregated model

Table C.4 – Variance inflation factors, disaggregated model

Variable	VIF	1/VIF
lnMTexpya	3.68	0.271775
lnHTexpya	3.18	0.314092
lngdpc	2.9	0.345135
lnhc15	2.47	0.404418
lnLTexpya	2.32	0.430442
lnRBexpya	1.33	0.750548
lnPexpya	1.28	0.781538
Mean VIF	2.45	

Analysis – Yet again our variance inflation factors all below 5 suggest that multi-collinearity is not a problem for our regression analysis.

10) Test for inclusion of time dummies, aggregated model

test _Iyear_1965 _Iyear_1970 _Iyear_1975 _Iyear_1980 _Iyear_1985 _Iyear_1990 _Iyear_1995 _Iyear_2000

(1) _Iyear_1965 = 0
(2) _Iyear_1970 = 0
(3) _Iyear_1975 = 0
(4) _Iyear_1980 = 0
(5) _Iyear_1985 = 0
(6) _Iyear_1990 = 0
(7) _Iyear_1995 = 0
(8) _Iyear_2000 = 0

F(8, 846) = 16.28
Prob > F = 0.000

Analysis – F-test rejects null that all coefficients on year dummies are zero, so we include them in our model specification.

11) Test for inclusion of quadratic terms, aggregated model

Table C.5 – Information criterion for quadratic terms, aggregated model

HC15	Adjusted R-squared	BIC	AIC
Unrestricted	0.1403	-3327.82	-3389.63
Restricted	0.1412	-3334.434	-3391.489
EXPYA			
Unrestricted	0.1411	-3328.59	-3390.4
Restricted	0.1522	-3334.434	-3391.489

Analysis – All three measures of goodness of fit suggest that our model gains little explanatory power from the addition of either quadratic term. Thus, we conclude not to modify our model.

12) Test for inclusion of interaction terms, aggregated model

Table C.6 – Information criterion for interaction terms, aggregated model

HC15	Adjusted R-squared	BIC	AIC
Unrestricted	0.1400	-3321.759	-3388.323
Restricted	0.1412	-3334.434	-3391.489
GDP/C			
Unrestricted	0.1399	-3327.444	-3389.254
Restricted	0.1522	-3334.434	-3391.489

Analysis – All three measures of goodness of fit suggest that our model gains little explanatory power from the addition of the interaction terms. Thus, we conclude not to modify our model.

13) Test for time dummies, disaggregated model

```
test  _Iyear_1965 _Iyear_1970 _Iyear_1975 _Iyear_1980 _Iyear_1985 _Iyear_1990
          _Iyear_1995 _Iyear_2000

 ( 1)  _Iyear_1965 = 0
 ( 2)  _Iyear_1970 = 0
 ( 3)  _Iyear_1975 = 0
 ( 4)  _Iyear_1980 = 0
 ( 5)  _Iyear_1985 = 0
 ( 6)  _Iyear_1990 = 0
```

(7) _Iyear_1995 = 0
(8) _Iyear_2000 = 0

F(8,   814) =   17.17
Prob > F =   0.0000

Analysis – F-test rejects null that all coefficients on year dummies are zero, so we include them in our model specification.

14) Test for inclusion of quadratic terms, disaggregated model

HC15	Adjusted R-squared	BIC	AIC
Unrestricted	0.1737	-3301.114	-3381.378
Restricted	0.1746	-3307.683	-3383.226
PEXPYA			
Unrestricted	0.1739	-3301.272	-3381.536
Restricted	0.1746	-3307.683	-3383.226
RBEXPYA			
Unrestricted	0.1737	-3301.039	-3381.303
Restricted	0.1746	-3307.683	-3383.226
LTEXPYA			
Unrestricted	0.1823	-3309.772	-3390.036
Restricted	0.1746	-3307.683	-3383.226
MTEXPYA			
Unrestricted	0.1744	-3301.826	-3382.09
Restricted	0.1746	-3307.683	-3383.226
HTEXPYA			
Unrestricted	0.1765	-3303.886	-3384.15
Restricted	0.1746	-3307.683	-3383.226

Analysis – Again, all three measures of goodness of fit suggest that our model gains little explanatory power from the addition of any of our quadratic terms. Thus, we conclude not to modify our model.

15) Test for inclusion of interaction terms, disaggregated model

HC15	Adjusted R-squared	BIC	AIC
Unrestricted	0.1900	-3283.392	-3391.984
Restricted	0.1746	-3307.683	-3383.226
GDP/C			
Unrestricted	0.1899	-3283.355	-3391.947
Restricted	0.1746	-3307.683	-3383.226

Analysis – Again, all three measures of goodness of fit suggest that our model gains little explanatory power from the addition of any of our interaction terms. Thus, we conclude not to modify our model.

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