PRIVATE CAPITAL INVESTMENTS IN AGRIFOOD-TECH STARTUPS IN SOUTH AMERICA

A Thesis

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Master of Science in Applied Economics and Management

by

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ABSTRACT

This research follows a mixed-methods approach to exploring private capital investment in agrifood-tech startups in South America. In the last 15 years, over $9.85 billion dollars have been allocated to finance 547 startups on more than 1106 business deals. The South American agrifood-tech ecosystem is heavily concentrated in Brazil and Argentina which account for 75% of the population of startups. Chile and Colombia have emerged as crucial players in recent years. The agrifood-tech sector shows the largest growth among all major industries; with an annualized growth rate of 52%, it accounts for almost 10% of total capital investments in the region. The top 10 largest deals account for almost 48 percent of all investments from the time series. The median investment in South America is roughly US$100,000. Pre-farm gate technologies captured over 42% of the deal flow but only 15% of the total capital invested. On-demand delivery startups represent 50.9% of all investments in the region but only 8.4% of the deal flow. 252 out of 547 firms raised two or more funding rounds from 2007 to 2022. Primary production is the industry segment in which startups reported repeated deal series (25%). Regression models with macroeconomic and macrofinancial indicators fail in explaining variation in private capital investments in South America. Private investment is positively and at least weakly significantly associated with the amount of land in agricultural production but not with the total output (AgGDP) from that land nor with the overall productivity (AgTFP) of the agricultural system. Overall, the main barriers to the adoption and uptake at scale of agrifood technologies in South America are limited access to financing, lack of sophisticated investors, poor public-private partnerships, high opportunity cost of on-farm technologies, weak domestic capital markets, and limited legal protection to investors.

BIOGRAPHICAL SKETCH

Juan Manuel Vergara was born in Santa Fe, Argentina. He studied agricultural engineering at Universidad Nacional del Litoral and joined Cornell University as a Fulbright Scholar to pursue his Master of Science degree in applied economics and management at the Dyson School of Business. Juan is enthusiastic about innovation and technology applied to agricultural food systems. He has a particular interest in studying the impact of capital investments on enabling and accelerating the uptake and adoption of agrifood technologies in Latin America. Before Cornell, Juan worked as a data scientist for the National Institute of Agriculture Research of France (INRA) and as an innovation leader for the Rosario Board Exchange (Rosario, Argentina), where he led the creation of an open innovation program for agrifood-tech startups in Argentina called “BCR Startup Network”. At Cornell, Juan joined Chris Barrett’s research team to participate in the production of FAO’s report “Agriculture Technologies and Innovations Outlook”.

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First and foremost, I would like to thank my friends and family for their endless love and continuous support along every single journey of my life. I would like to extend my sincerest appreciation to my thesis supervisor, Dr. Chris Barrett, for his invaluable guidance, expert knowledge, and unwavering support throughout this research endeavor. I would also like to express my gratitude to the Fulbright Commission and Cornell University for their financial support towards my academic pursuits. I would like to thank my roommates David and Max for their friendship and support during my time at Cornell. I would like to thank all the industry experts interviewed and to the member of my thesis committee, Mario Herrero, for their time and their contribution to this study. Lastly, I would like to thank AgFunder, Louisa Burwood-Taylor, and Cornell professor Matt Marx for making data on private investments in South America available to me.

Thank you all.

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1 Introduction

The agricultural and food technology (agrifood-tech) sector is a subset of the entrepreneurial ecosystem focused on creating new solutions and services with the goal of improving and disrupting global food production, processing, distribution, delivery, and consumption. As with all industries, technology plays a key role in the operation of the agricultural food sector. Responsible for feeding the world and employing over 27% of the global population, the global food and agriculture industry is estimated to be worth $10 trillion or over 12% of global GDP (World Economic Forum, 2022).

The global agrifood sector is currently facing major challenges such as climate change, population growth, limited land, labor scarcity, and food waste (D. Charlton, 2021; Rockström et al., 2017; FAO, 2011; Parfitt et al., 2010). What all these challenges have in common is that they are urgent and complex to resolve because they are multidimensional and involve multiple stakeholder groups that do not have the same understanding of the problem and potential solutions (Levin, Cashore, Bernstein, & Auld, 2012) The effect of implementing global solutions to these challenges remains highly uncertain and unpredictable, studies on defining impact pathways for several technology and innovation uptakes have shown that unintended spillover effects on non-target objectives are always likely (Herrero et al., 2021; Barrett et al., 2022).

Promising new technologies to face these challenges have captured the attention of venture capital and private equity funds. Over the past decade, global private capital investments in agrifood-tech startups have skyrocketed, increasing from US$ 3.1 billion in 2012 to $29.6 billion in 2022 (AgFunder, 2023). South America has been anything but an exception to this phenomenon. According to the findings of this study, private capital investments in agrifood-tech startups

increased from US$ 79 million to US$ 1.87 billion during the same time span, representing a 2200% increase over a decade.

Surprisingly, little is known about the impact of all these investments on shaping the South American agrifood-tech ecosystem. There are no previous studies that have measured the direction and magnitude of agrifood-tech investments in South America. Moreover, data availability is fragmented and limited to primary production, when more than 70 percent of the value addition reflected in consumer food expenditures globally occurs post-farmgate (Yi et al., 2021). Intentional management of agricultural food systems toward more sustainable, equitable, and resilient systems is most likely if accurate and reliable data and measurements on investments in development and uptake are available and used.

The current direction, magnitude, and pattern of evolution of the South American agrifood ecosystem remains unknown. Measuring agrifood technological progress in South America is crucial for a number of reasons. First, previous studies showed a significant positive relationship between FDI and economic growth (V. Owusu-Nantwi, 2019). According to data from the World Bank, the agriculture sector's contribution to GDP in South America in 2020 ranged from 4% to 6% for major economies. Technological progress can play a significant role in increasing productivity, improving food security, and reducing poverty. Technological progress requires up front investments.

Second, measuring investments in agrifood-tech can help identify gaps in research and development, and guide policymakers in making informed decisions regarding funding and resource allocation. By monitoring progress towards the SDGs, South American countries can better target their efforts and resources towards achieving sustainable development. Third, advances in agrifood technology can contribute to several SDGs, such as zero hunger (SDG 2),

good health and well-being (SDG 3), and climate action (SDG 13). By measuring progress towards these goals, South American countries can demonstrate their commitment to sustainable development and enhance their chances of achieving them.

The objective of this research is to analyze historical data in agrifood-tech private investment flows in South America in order to identify trends, correlates, and heterogeneity among countries and sub-sectors, including the accelerators and barriers to progress. For several agricultural technologies and innovations drawing significant private investment in South America, we expect to identify accelerators or barriers to adaptation and uptake at scale and how these influence investment patterns. In addition, this project aims to generate evidence on the difficulties of accessing and gathering structured data on private capital investments.

The rest of the paper is organized as follows. Section 2 discusses the limited literature on agrifood technology and innovation in South America, with a special emphasis on private capital investments. Section 3 introduces the methods and data employed in this research. Section 4 provides an overview of the past and current state of South America's agrifood-tech ecosystem. Section 5 discusses the empirical model used to study patterns of private investment flows. Finally, Section 6 discusses accelerators and barriers to technology uptake in South America and concludes.

2 Literature Review

The Inter-American Development Bank published a report in 2019 highlighting the incredible technological innovation expansion observed in Latin America and the Caribbean agricultural and food sectors (IDB, 2019). The report maps the distribution and demography of the agrifood-tech startups present in the region, as well as the most common financing vehicles employed by entrepreneurs to finance their businesses. It identifies current trends in agrifood technologies in the region. It proposes nine key areas of technological innovation with great potential to shape Latin America's agrifood ecosystem. Nonetheless, this report does not provide any measure of investment, nor any analysis of how the allocation of private capital varies across countries and technologies.

Several studies have focused on diagnosing the current situation of the agrifood-tech ecosystem in South America at a country level with a special emphasis on the company. All these studies have contributed evidence on the universe of startups present in the region, how startups add value to the agricultural supply chain and help small and medium farmers to incorporate new technologies, and how the innovative business model of agrifood-tech startups drives internationalization, just to mention some examples (G. B. Silveira, 2022; V. L. Vargas, 2023; A. Cavallo, 2020).

In addition, we find interviews conducted with agrifood-tech startups from Argentina and Brazil that provide a picture of what is the current state of the agrifood ecosystem in those countries. Heavy intervened markets and high technology costs are among the main factors that negatively impact technology uptake in the region. Meanwhile, dense institutional bureaucracy reduces innovation efforts. Brazil shows the highest rate of digitalization among its agriculturalist

with 46% of them using some digital media, surpassing American and European producers who presented a usage rate of 31% and 22%, respectively. (J. Lachman et al., 2021; Dias, C., Gonçalves, 2020)

Recent studies have shown that foreign direct investments have a positive significant long-term effect on promoting economic growth in South America (Owusu-Nantwi, 2019). Domestic capital abundance, free markets, and population growth have a positive impact on economic growth in South America, whereas government expenditure and high inflation rates have a negative impact on growth. In addition, moderate public investments in critical infrastructure, health, and education may produce positive spillover by stimulating private capital formation and economic growth (M. Ramirez, 2000).

Despite the promising benefits of private capital investments on socio-economic welfare, historical data indicates that 10-year average returns on investing in Latin American emerging markets have continuously underperformed the average for both emerging and developed markets. According to the Morgan Stanley Capital International (MSCI) Emerging Markets Latin America Index, which tracks the performance of large and mid-cap stocks in the region, the average annual return for the period from 2012 to 2022 was around -1.43%, while for the MSCI Emerging Market and the MSCI ACWI Investable Market indexes the returns were 2.37% and 8.47%, respectively (figure 1).

Structured data on capital investments into agrifood-tech companies are currently scarce in South America. Moreover, in most of the countries in South America, no public or governmental institution actively tracks these investments and provides accurate structured information on agrifood-tech companies. Some companies have seized this opportunity and, as a result, several commercial data providers have flourished in recent decades.

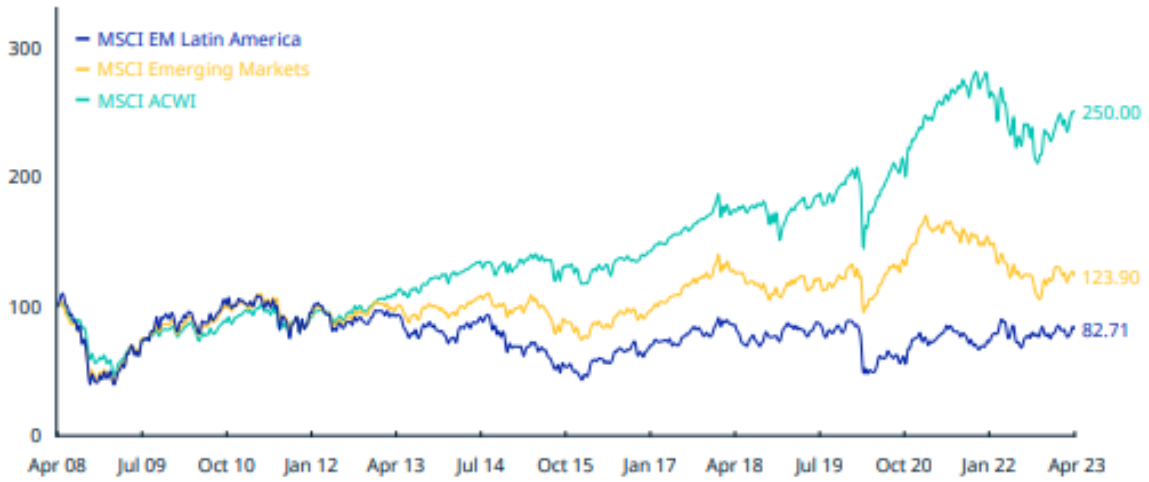


Figure 1: Historical cumulative performance of (i) MSCI Emerging Market Latin America (blue), (ii) MSCI Emerging Markets All (yellow), and (iii) MSCI ACWI Investable Markets index from April 2008 until April 2023.

To summarize, to date there is no literature on private capital flows committed to financing agrifood-tech startups in South America, nor on linking these investments to country-level socio-economic indicators that may explain the rapidly expanding sums of money flowing into regional economies.

3. Data and Methods

This research follows a mixed-methods approach to exploring private capital investment in agrifood-tech startups in South America. We conduct a quantitative, multivariate regression analysis of current and past patterns of financial investment into agrifood-tech startups in South America and explore the correlations between the disbursement of private capital investments and social and economic indicators. We complement this with a qualitative analysis of key accelerators and barriers to the adaptation and uptake at scale of agrifood-tech innovations in South America.

Agrifood systems (AFS) are defined as the entire range of actors, and their interlinked value-adding activities, engaged in the primary production of food and nonfood agricultural products, as well as in storage, aggregation, post-harvest handling, transportation, processing, distribution, marketing, disposal, and consumption of all food products including those of non-agricultural origin. The AFS thereby encompasses the whole value chain, from input suppliers to primary producers upstream to food consumer-facing companies downstream (FAO, 2022).

There is no formal definition of an agrifood-tech startup. Nonetheless, the literature agrees on defining an agrifood-tech startup as a young company that is intense in the use of technology, highly innovative, has a scalable business model, and its mission is to improve and transform the agriculture and food industry by increasing efficiency, sustainability, and productivity in the food supply chain, from farm to fork (A. Connolly, 2018; D. Cockayne, 2019). Agrifood-tech startups can operate in various sectors of the industry, also called *industry groups*, some examples of industry groups include but are not limited to primary production, storage, transport, distribution, finance, and food services.

The object of study of this research are private capital investments in agrifood-tech startups headquartered in South America. Currently, there is no pre-existing data set available. So we had to compile, merge, and de-duplicate data from AgFunder (AF) and Pitchbook's (PB) databases and complemented with entries derived from our independent research on governmental and media websites. AF and PB data sets were framed differently and included different variables. Nonetheless, both of them reported a similar number of US dollars invested for the time series but only shared in common 47% of reported deals. Hence, we worked closely with AF and PB representatives to understand their data generation process and data entry methodology. The merged data set consists of 1,106 deals conducted by individual investors, private institutions,

accelerators/incubators, private equity (PE), and venture capital (VC) firms on 586 agrifood-tech startups from South America. Mergers and acquisitions were excluded from the analysis given to a lack of availability and reliability of data on business deals conducted by corporations given that they are frequently kept under the carpet due to corporate's strategy reasons. Nonetheless, corporations play a key role in the ecosystem by acquiring early-stage promising businesses and leveraging their growth by providing them with infrastructure and resources various. Table 1 shows the distribution of deals based on investor type classification.

Deal Type	No. Of Deals	(%)
Venture Capital	**962**	**86.98**
1. Angel (Individual)	41	3.71
2. Accelerator/Incubator	204	18.44
3. Early-Stage VC	585	52.89
4. Late-Stage VC	132	11.93
Private Equity	**95**	**8.59**
Grant	**29**	**2.62**
Debt	**20**	**1.81**
Total	**1,106**	**100**

Table 1: Distribution of investments sample based on investor type classification.

We analyzed two alternative methodologies to track investments in science, technology, and innovation (STI). The first alternative we explored was an expenditure-based approach, where investments are recorded as a function of expenditures on AFS-STI R+D. This approach has the advantage of being more accurate as there is a perfect correlation between expenditure and time. Nevertheless, the availability of structured data on STI R+D expenditures is scarce and limited to publicly traded companies and governmental entities. Methods of accounting for R+D expenditures also follow different accounting practices limiting infer-firm comparability. The

second alternative, and the one we choose, is a revenue-based approach, where investments are recorded as financing flows. The drawback of this approach is that we cannot estimate when firms spent the money and into which activities.

In addition, there is no regulation that obligates firms to disclose information related to funding, thus total investments in the region remain unknown. This is even more likely for private equity firms where big industry players prefer to keep their deals under the radar for several reasons such as deal flow management, reputation management, strategic and competitive advantages, public opinion, and regulatory considerations. Thus, private equity deals are likely disproportionally underreported in our sample data.

The advantage of the revenue-based approach is that there are data providers that offer structured data on investments, making it easier to estimate, as we only need to know the recipient and size of the investment. In this study, we therefore opted for a revenue-based approach.

Private capital funding events are often labelled ‘funding rounds’. A funding round is a term used to describe the process of raising money from investors, typically in exchange for equity in a startup company. In VC, there are several different types of funding rounds that a startup may go through as it grows and develops. The most common types of funding rounds are (i) Seed round, (ii) Series A round, and (iii) series B, C and beyond. Seed and Series A rounds are considered early-stage VC, series B and beyond are late-stage VC rounds. Seed funding is usually used to help a company get off the ground, develop its initial product or service, and start to build its team. The terms and conditions of each funding round, including the amount of equity that investors receive in exchange for their investment, are negotiated between the startup and the investors. These negotiations can be complex and involve many different factors, such as the startup's

valuation, the investors' expectations for returns, and the level of control that investors will have over the company.

The period of analysis of this study runs from the beginning of 2007 to the conclusion of 2022. Entries prior to 2007 are insignificant in magnitude and discontinuous in time, so we decided to exclude them from the study. Deals were indexed to a company and deal ID in order to unequivocally identify them and subsequently grouped by year and country, in which the startup is headquartered. All entries were recorded in US dollars and converted to real US dollars base year 2022 using the adjust_for_inflation function available on R Studio package *priceR*, which retrieves historic Consumer Price Index data from World Bank's database.

Companies were manually classified into one of nine industry groups proposed by the USDA and later adapted and expanded by the Food Systems Dashboard (Food System Dashboard, 2020). The Industry Group Series classification allows us to identify the segment of the value chain where the startup adds value. Classifications were assigned based on three parameters: i) company description (provided to data providers by the company itself), ii) data providers' own classification system, iii) professional interpretation based on team expertise. Subsequently, startups were fitted into 1 of 14 technology groups proposed by the research team. Technology groups were defined based on the technology domains proposed by Herrero et al. (2020) and expanded by Barrett et al. (2022) and AgFunder's technology classification, which is fairly standard within the industry.

The purpose of classifying investment flows into various technological and industrial categories is to identify historical and current trends in agrifood-tech and to measure the direction and scale of development of South America's agrifood ecosystem. Our goals are i) to show how

investments into agrifood-tech startups in South America have increased over time, and ii) to determine if investments are shifting in their geography or sub-sector foci.

After identifying descriptively the technology and industry segments that attract the largest investments, we discuss the main accelerators and barriers to the development of the ecosystem. We will run a multivariate regression model with multiple levels of fixed effects to explore what socioeconomic, macroeconomic, and production indicators explain the variations observed in private capital inflows, controlling for a range of unobservable factors. The explanatory variables included in the model diagnose country performance in various dimensions such as innovation, agriculture production, sovereign debt, government expenditure, and so on. Table 2 shows the list of variables in the final dataset.

Finally, outcomes from the regression analysis complemented with interviews[1] with industry experts will be employed to elaborate a comprehensive review of the main barriers and accelerators to the adoption and uptake to scale of agrifood technologies and innovations in South America.

[1] José Gobbé (The Context Network), Martin Burló (Red Surcos SRL), Trevor Sieck (FoodBytes by Rabobank), Tomás Peña (The Yield Lab), Ernesto Stein (IDB Lab), Ana Castillo Leska (IDB Lab), Matias Peire (GRIDX), Roberto Vitón (Valoral Advisors), Juan Ortega (Rappi), Jeremías Latchman (University of Buenos Aires).

Column	Variable Name	Description
1	DealID	The primary key for the deal.
2	DealYear	Year in which the financing event was completed. DealYear range: 2007-2022.
3	CompanyID	Unique identifier for the company involved in the deal.
4	CompanyName	Name of the company receiving the financing.
5	HQSubRegion	The region in the world where the startup is headquartered, i.e. South America.
6	HQCountry	Country where the startup is headquartered (e.g. Argentina, Brazil, Chile, etc).
7	Vertical	Venture Capital startup vertical. Categories: Agtech, Biotech, Foodtech, Fintech, Insurtech
8	Industry Group	USDA Industry Group Series adapted and expanded by the Food System Dashboard. Categories: (i) Agriculture Inputs, (ii) Primary Production, (iii) Storage, Transport, and Distribution (STD), (iv), Processing and Packaging, (v) Marketing and Retail, (vi) Consumption, (vii) Finance, and (viii) Cross-cutting Innovation).
9	Technology Group	Technology groups proposed by Agfunder's agrifood-tech reports and adopted and expanded by our research group. (i) Ag Biotech, (ii) Bioproducts, (iii) Circular Economy, (iv) Cloud Infrastructure, (v) Digital Agribusiness, (vi) Food Safety and Traceability, (vii) Food Services, (viii) Home & Cookingtech, (ix) Innovative Food, (x) Insurtech & Fintech, (xi) Intensification, (xii) Robotics and Automation, (xiii) Smart Farming, (xiv) On-demand Delivery.
10	DealSize	Total amount of capital invested into a company by an investor or group of investors for a specific transaction (USD millions)
11	DealSize_Adj	Millions of USD reported in the financing event adjusted by inflation to the base year 2022 using R package 'priceR' (Current USD millions).
12	DealType	Identifies and categorizes distinct types of transaction or financing rounds between an investor and company. Categories: (i) Angel Investor, (ii) Accelerator/Incubator, (iii) Early-stage VC, (iv) Late-stage VC, (v) Private Equity (PE), (vi) Debt, and (vii) Grant.
13	FinancingStatus	Represents the type of investors that are financially backing the company at the time of the deal. Categories: (i) VC-backed, (ii) PE-backed.
14	VCRound	Venture Capital financing round. Categories: (i) Seed, (ii) Series A, (iii) Series B, (iv) Series C, (v) Series D, (vi) Series E, and (vii) Series F.
15	TotalInvestedCapital	Amount of capital (equity and net new debt) put in by the investor. Amount in current USD millions.
16	AgGDP	Contribution of Agriculture to GDP of country stated in HQCountry during year = DealYear (% of total GDP). (Source: World Bank).
17	AgLand	Agricultural land area of HQCountry, in millions of hectares. (Source: FAOSTAT)
18	AgTFP	Agriculture Total-Factor-Productivity for country and year stated in HQCountry and DealYear (Source: USDA)
19	Net_Capital_Stock	Net capital stock per capita in millions of US dollars in country and year stated in HQCountry and DealYear (Source: FAOSTAT)
20	EMBI	The average annual score of the Emerging Market Bond Index for country and year stated in HQCountry and DealYear. (Source: J. P. Morgan - BCRD).
21	GE	Government expenditure in agriculture in country and year stated in HQCountry and DealYear (current USD millions). (Source: FAOSTAT)
22	GII	WIPO - Global Innovation Index for country and year stated in HQCountry and DealYear. (Source: World Intellectual Property Organization)

Table 2: Description of the list of variables included in the generated dataset.

4. The Agrifood-tech ecosystem in South America

4.1 Historic evolution of private capital investments

The agrifood-tech ecosystem in South America has shown steady growth over the past 15 years, with increasing investments and a growing number of deals conducted. Figure 2 shows the historical evolution of private capital investment in agrifood-tech startups in South America from 2007 to 2022. It shows a clear upward trend in private capital investment in the region, with a considerable dip in 2020 due to Covid-19 that is followed by a strong recovery in 2021. Nearly $61 million in investments were excluded from the analysis because of missing deal date data.

The total amount of private capital committed to startups from 2007 until 2022 adds up to $9.85 billion constant 2022 US dollars. The data on the real investments in agrifood-tech startups in South America show a significant increase from $1.9 million in 2007 to a peak of $2.371 billion in 2021. The peak observed in 2021 can be attributed to two reasons. First, several deals that were expected to be conducted in 2020 were delayed to the next year as VC funds waited for more clarity in the market during the early stage of the Covid-19 pandemic. Second, Covid-19 boosted the use of delivery and grocery apps, which drew a large sum of new private capital flows in 2021. The agrifood sector was one of the few that never stopped working during the pandemic, even if individual enterprises closed.

Nominal investments have followed the same trend during the last 15 years. If we focus on the last decade, investments in the agrifood-tech field have continuously increased at a compound annual rate of 51%. The fall in investment flows in 2022 may be explained by an increase in interest rates globally which reduced cheap money flows to startups. The difference between 2021 and 2022 private capital investments will also gradually shrink as more deals 2022 get reported during the course of 2023.

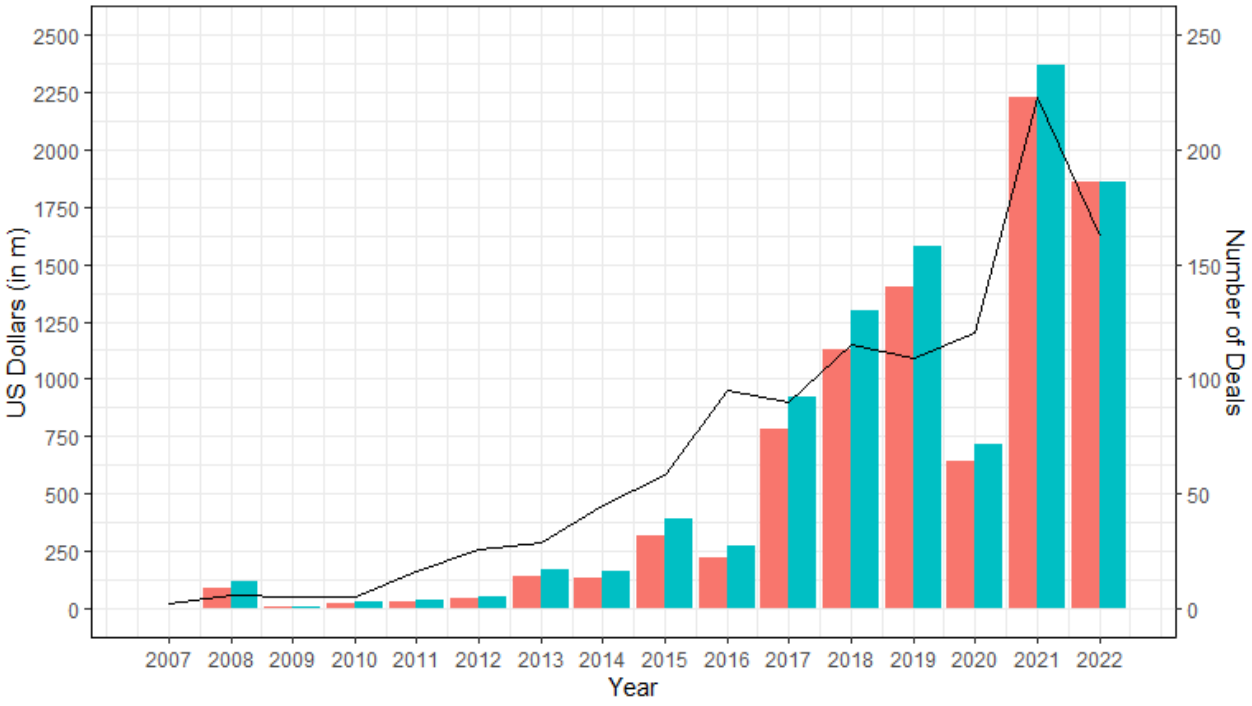


Figure 2: Historic evolution of capital investments in South America from 2007 until 2022. The bar graphs represent the amount of nominal US dollars (red) and constant 2022 US dollars (green) invested in South America in the corresponding year, the line represents the evolution in deal volume.

The number of deals conducted in South America has also increased steadily over time, with a peak of 224 reported deals in 2021. The number of transactions per year grew gradually from 5 in the first decade of the 2000s to over 120 in 2019, before skyrocketing to over 200 in 2021 and 2022 as Covid-19 accelerated the digitalization of South America.

The average deal size for the region is $9.2 million US dollars. Nevertheless, this metric is highly affected by outlier funding rounds. The top 10 largest deals account for almost 48 percent of all investments from the time series. Hence, the median offers a more accurate metric to describe the ecosystem. The median deal size for South America is $100 thousand US dollars.

South America's agrifood sector is primarily characterized by a large number of early-stage funding rounds. Early-stage funding rounds account for all investing rounds previous to a series B round. The most common deal types are seed rounds (36%) and funding rounds led by accelerators

and incubators (20%). Together, these represent 56% of all deals conducted in South America over the study period.

Although the investment figure seems to be large, it is relatively small when compared to South America's government expenditure on agriculture. In 2021, governments from South America spent over $5.5 billion dollars on agriculture. Brazil holds the largest expenditure on agriculture with $3.7 billion dollars which is reasonable considering its population and agricultural land (FAOSTAT, 2022). Interestingly, over 1/4 of Brazil's budget is allocated to support R+D activities. On the other hand, Argentina's budget for agriculture is relatively small when compared to its country's size. In 2020, Argentina's government spent roughly $267 million dollars in agriculture while its neighboring country, Chile, which has 40% of the population and 15% of the agricultural land of Argentina, allocated over $743 million dollars on agriculture.

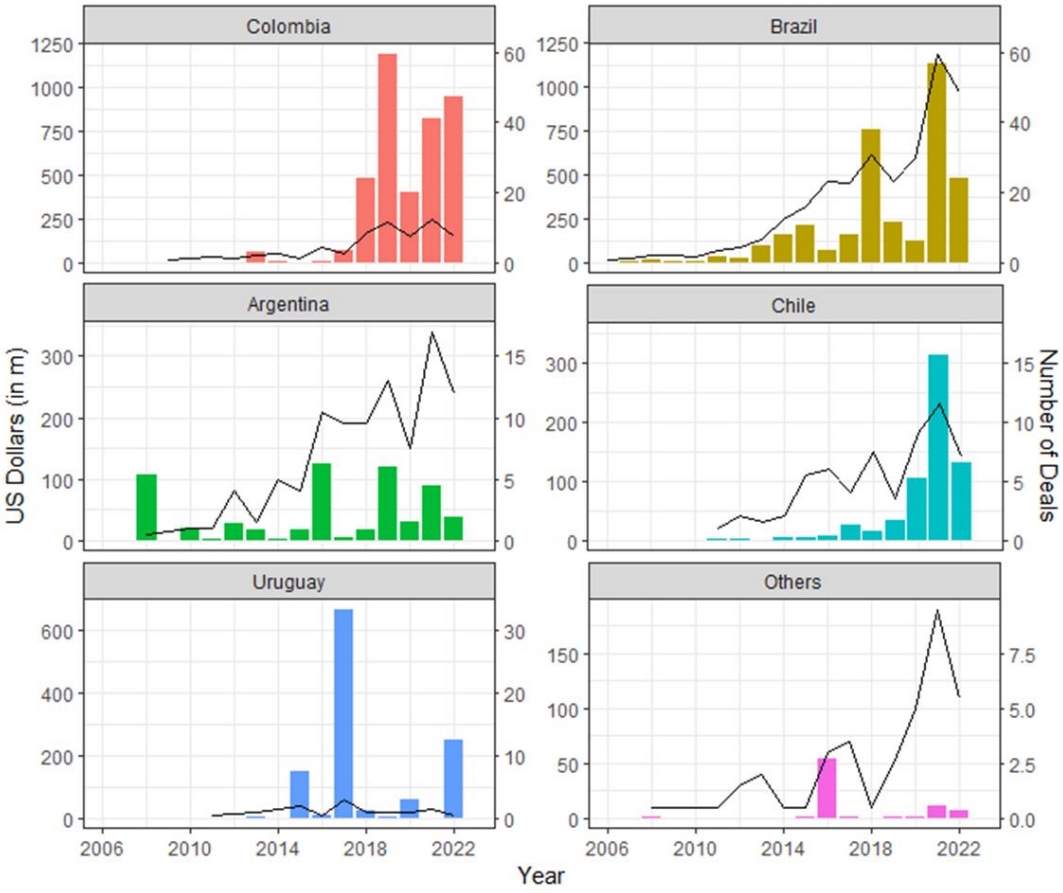
Figure 3 shows the evolution of agrifood-tech investment among the major agricultural countries of South America. There is a clear upward trend in cumulative investment and the number of deals reported in the region. Argentina, Brazil, and Colombia are leaders of the segment, attracting larger sums of capital and closing more deals than their neighboring countries. Startups are heavily concentrated in Brazil and Argentina, representing 70% of the population of the agrifood-tech startups in the region, consistent with Viton et al. (2019). On the other hand, Colombia and Chile hold a similar population of startups, but they significantly differ in the amount of capital that their startups raise.

Second, during the last decade, Chile has consolidated as a relevant player in agrifood-tech field despite its small agricultural land. One of the main reasons for this phenomenon is that Chile ranks first in the region in the World Bank's 'Ease of doing business' ranking, closely followed by Colombia. Since 2005, Chile and Colombia conducted over 40 structural reforms to facilitate the

opening of new businesses and the disbursement of foreign direct investment into the country. Argentina and Brazil rank last for the same indicator within the countries included in this study.

Third, countries like Uruguay have a low volume of deals and startups but still raise considerable amounts of money. This situation can be illustrated by PedidosYa (Uruguay) and Rappi (Colombia), two delivery apps that are turning into 'super' apps that have raised rounds of $250 and $1,000 million dollars, respectively. These outliers should be taken into account when making conclusions about the state of the agrifood ecosystem of certain countries. If we adjust by population size, the number of agrifood-tech startups in Uruguay would be similar to the number recorded for Argentina with approximately 0.3 agrifood-tech startups for every 100,000 inhabitants.

The growing interest in agrifood-tech investments in South America is likely driven by several factors, including the increasing demand for food and the need to improve agricultural productivity, as well as the growing awareness of the environmental and social impact of the food industry. Moreover, as we will discuss later, the emergence of innovative technologies and business models, such as precision agriculture, remote sensing, digital markets, and food services, has also attracted investors looking for disruptive opportunities.



Country	$ (%)	DV (%)
Argentina	7.1%	17.5%
Brazil	35.5%	51.6%
Chile	7.0%	11.2%
Colombia	38.8%	10.8%
Uruguay	10.9%	2.0%
Others	0.7%	6.9%

Figure 3: Historic evolution of private capital investment in agrifood-tech startups in major agricultural countries of South America. The bars represent the aggregated sum of investments in constant 2022 US dollars for different countries, and the solid line is the number of deals reported over the study period.

4.2 Cross-sectoral comparison

This section seeks to understand how well the agrifood-tech sector is performing when compared to other industry and technology sectors and within neighboring countries. We used Pitchbook's historical investment data to estimate the aggregated inflows of private capital by industry sectors from 2007 to 2022. Figure 4 shows the evolution of the share of each industry sector in the total amount of private capital flows over the time.

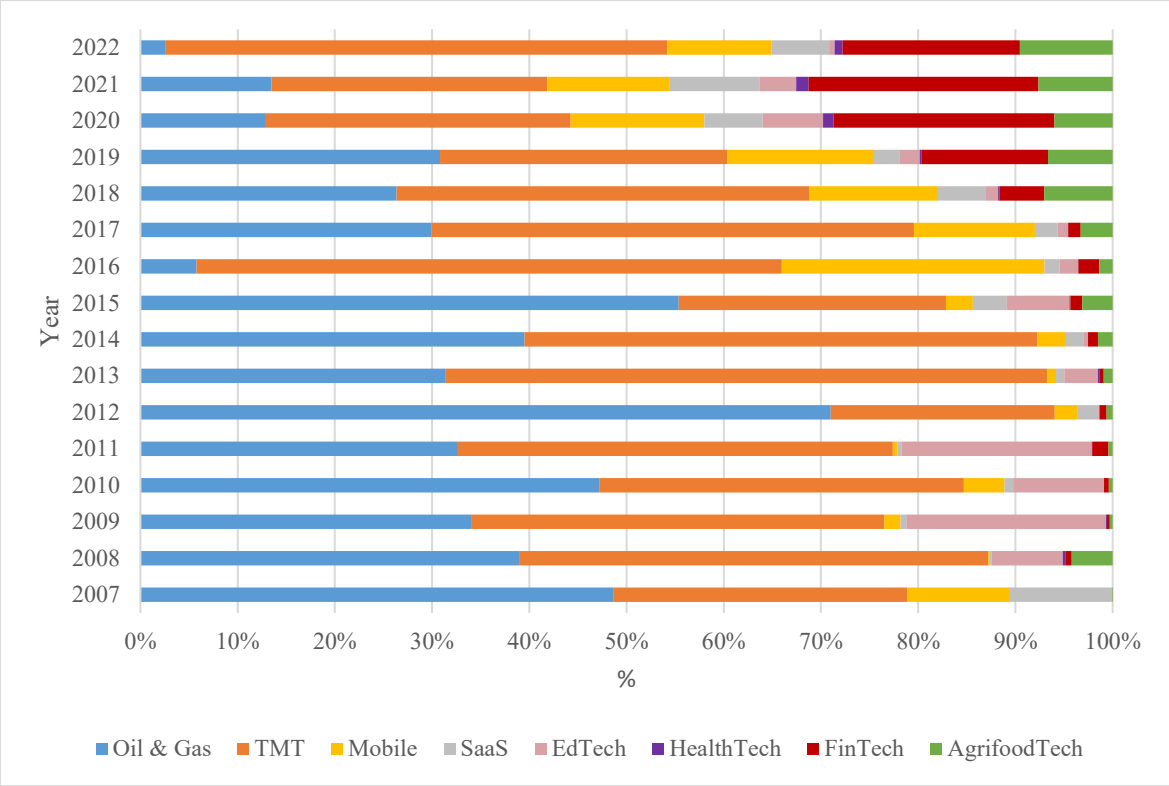


Figure 4: Share of eight major industry segments on total private capital investments in South America by year. TMT accounts for telecommunication and media technology.

We can appreciate that until 2015, investment flows were heavily concentrated in the oil & gas and telecommunication segments, accounting for over 80% of private capital investments. After 2015, new industry sectors started gaining predominance and claiming the attention of investors. Together, the mobile, software, fintech, and agrifood-tech sector represents 50% of private investment flows. In the last 5 years, agrifood-tech alone captured 7 to 10% of investments in South America. Agrifood-tech and fintech are the segments that showed the largest growth with an annualized compound rate of 52% and 49%, respectively. They are followed by the software industry with a 31% year-over-year growth. Health-tech and educational-tech run behind with an estimated annualized growth of 24% and 12%, respectively.

This representation is important because it helps us to understand the relevance of agrifood-tech sector when compared with other major industries. Besides underreporting is pervasive there is no particular reason to assume that underreporting should be different in agrifood-tech than in other sectors.

4.3 Capital investments by value chain segment

Figures 5 and 6 show the evolution of private capital investment in constant 2022 US dollars in South America by agrifood value chain segment. Growth in investments appears across all value segments. Private capital investments in South America grew gradually over the first decade, with exponential growth in the last five years.

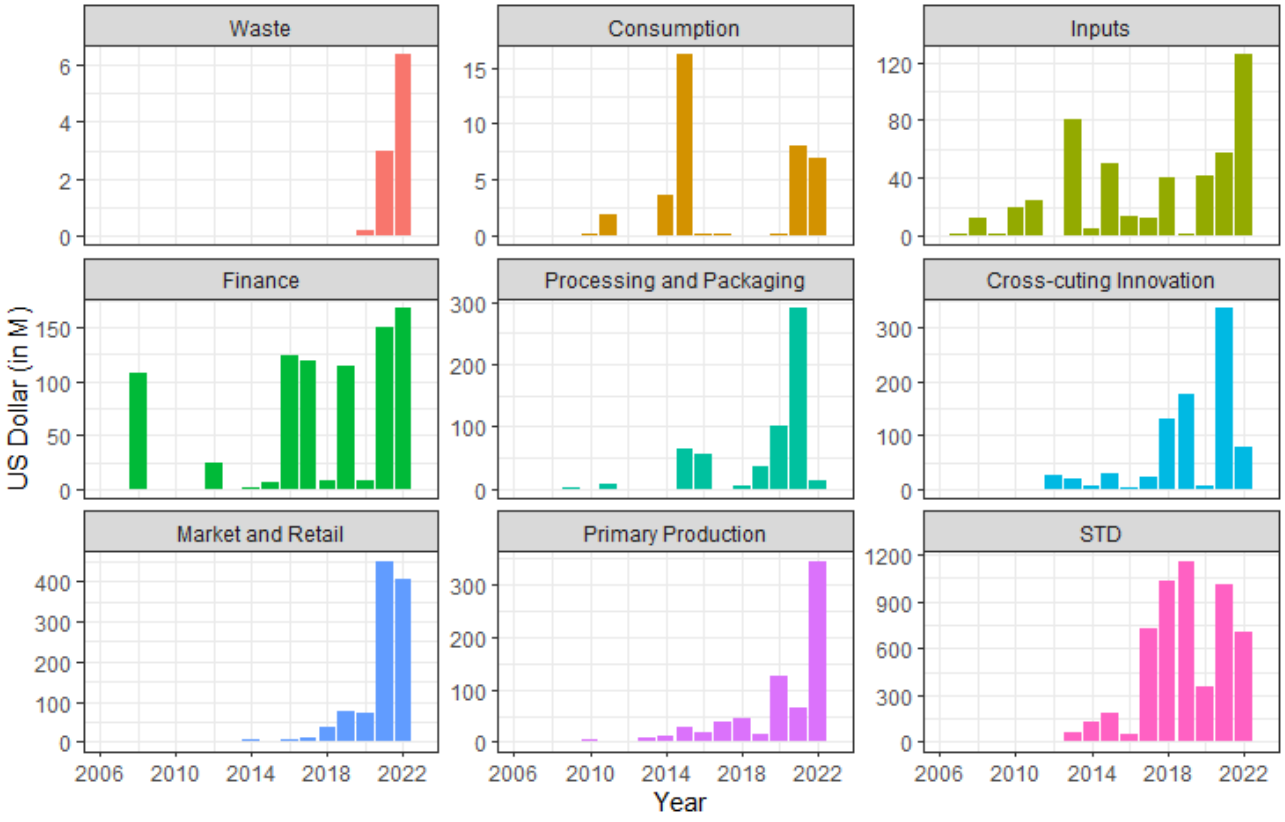


Figure 5: Evolution of private capital investments in US constant 2022 dollars in South America by value chain segment from 2007 until 2022. STD corresponds to Storage, Transport, and Distribution.

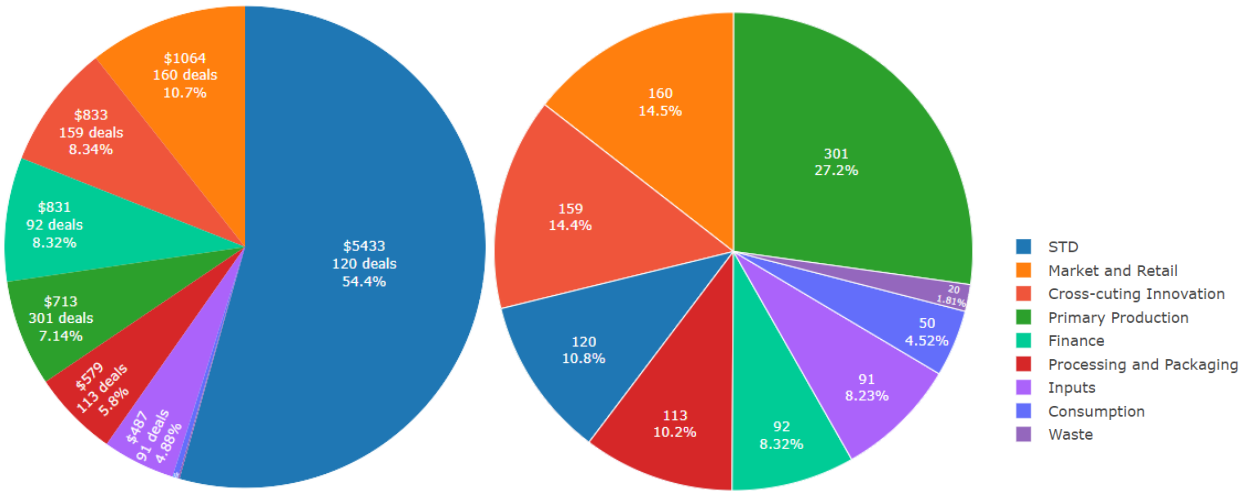


Figure 6: Pie chart that shows the participation of every technology group based on total invested capital (left) and deal volume (right) in agrifood-tech startups in South America from 2007 until 2022. STD corresponds to Storage, Transport, and Distribution.

Storage, Transport, and Distribution (STD) is the segment that has attracted the largest investments during the last decade with $5.43 billion of US dollars committed to startups, representing 54.4% of total agrifood-tech investments in South America. This reflects the high level of capital required for infrastructure. Roads, railroads, and inland ports play a significant role in the long-distance transportation of agricultural goods and fertilizers in Brazil, Argentina, and Chile. Therefore, reliance on transportation and logistics networks maintains countries' competitiveness, and continuing growth is anticipated to spur the development of the South American STD segment. STD ranks fourth in deal volume with 10.8% of market share, indicating that deal sizes are especially large in STD.

Primary production ranks first in deal volume among all industry segments with 301 deals (27.2%) completed in the past 15 years, and fifth in capital invested with $713 million (7.14% of total invested). Investments in this industry sector have increased over time as well as the number of deals conducted.

The marketing and retail segment has increased exponentially after Covid-19, as digital marketplaces overcame farmers' resistance to trying new tools. The marketing and retail industry ranks second in deals volume and in capital invested with 160 deals and $1.06 billion, respectively. Marketing and retail account for 10.7% of private capital investments in South America. South America is the market leader in this sector, and between 2022 and 2027, e-commerce is predicted to rise by 19%, outpacing the global average of 14% (Mordor Intelligence, 2022).

Processing and packaging of agricultural products follow the same trends as the demand for processed food such as plant-based, lab-growth meat, and frozen food products increases globally. It ranks sixth in terms of deal volume, close to the STD segment with 113 deals and 10.3% share of deal volume. Nevertheless, with $579 million on investments it represents only 5.8% of total investments in the region as these deals are relatively small.

Cross-cutting innovation refers to all technological solutions that support the enabling environment, like cloud infrastructure, block-chain technologies, regulation, etc. In a similar fashion to marketing and retail, this industry has experienced incredible growth during the last decade as the digitalization of the agriculture supply chain boomed. Cross-cutting innovation ranks third in both deal volume and capital raised with 159 deals and $980 million dollars in capital. Almost 10% of capital inflows in the region are directed into this segment which accounts for 9.17% of deal volume.

Finance is one of the segments that has remained more stable during the time span. It ranks fourth on capital invested with $831 million and sixth in deals volume with 92 deals directed to backup startups. It contributes with 8.32% of market share for both deal volume and capital invested. Fintech has a huge penetration in South America where levels of financial inclusion are low; only 50% of the population has a bank account and less than 21% own a credit card (A.

Demirguc-Kunt et al., 2019). The literature often attributes insufficient financial inclusion to institutional weaknesses, low levels of bank competition resulting in high financial service costs, insufficient infrastructure, and an overly restrictive regulatory environment (Dabla-Norris et al. 2015b, Fishbane 2014, and Rojas-Suárez 2016). Thus, fintech startups find lots of room to grow in South America aiming to alleviate financial frictions and improve financial inclusion (M. D. Gershenson et al., 2021).

Agricultural inputs refer to all resources and materials used in the production of crops, livestock, and other primary agricultural products. These inputs include a wide range of products, such as fertilizer, machinery, seeds, feed, and so on. Agricultural inputs follow a similar pattern as finance. This segment is highly concentrated in a few corporations that produce the inputs. Generally, startups in this sector are acquired in their early stages by large corporations to develop their technologies in-house through corporate venturing programs. That is one of the main reasons why inputs rank seventh in the list with 8.23% share of deal volume (104) and 487 million dollars in capital invested (4.9 %).

Finally, consumption and waste management rank last in South America, representing roughly 0.9% of the investments. Consumption accumulated 70 deals and 48 million dollars in funding since 2007. Consumption is represented by kitchen appliances, food & nutrition apps, cooking-tech, and so on. Waste management technologies have drawn increased recent funding as societal awareness of the environmental consequences of food loss and waste strengthens. Solutions that promote the re-use, recycling, and reduction of waste are extremely important for the development of the region. Nonetheless, it ranks last among industries for both deals and capital invested with just 20 deals and $10 million raised.

4.4 Capital investments by technology group

Private capital investments across all 14 technology groups have shown a steady growth over the last 15 years, with increasing deal sizes and numbers of deals completed. Figures 7 and 8 exhibit past and current trends in technology in the region, figure 7 presents the historical evolution of capital investments in constant 2022 million US dollars by technology group and year in South America. Figure 8 complements the analysis by providing measures of deal volume and capital captured by technology segments.

On-demand delivery technologies alone explain 50.9% of total capital investment in the region although it only represents 8.4% of deal volume with 103 deals since 2007. 8 out of 10 largest deals were for food delivery apps such as Rappi, iFood, PedidosYa, and JOKR. These eight deals alone add up to 3.6 billion dollars and represent 39.3% of the total capital invested in South America during the past 15 years.

Cloud infrastructure accounts for 9.11% of capital inflows with $974 million in raised capital and for 12.1% of deal volume with 48 deals reported. Cloud infrastructure technologies were catapulted by the growth of on-demand delivery apps as they provide back-end solutions for most of these digital applications. At the same time, these technologies help restaurants and grocery shops to manage orders, simplifying their work. They also facilitate payments and provide software management tools to digitalize different segments of the supply chain.

Insurtech and fintech take third place in the rank with $831 million dollars in investments and represent 7.8% of deal volume. As already mentioned, fintech is a very attractive area for venture capitalists that are interested in investing in South America. Agriculture is a risky activity by nature and startups that develop solutions to mitigate climate risk find fertile soil to conduct business. It ranks seventh in deal volumes with a share of 8% on 98 deals completed.

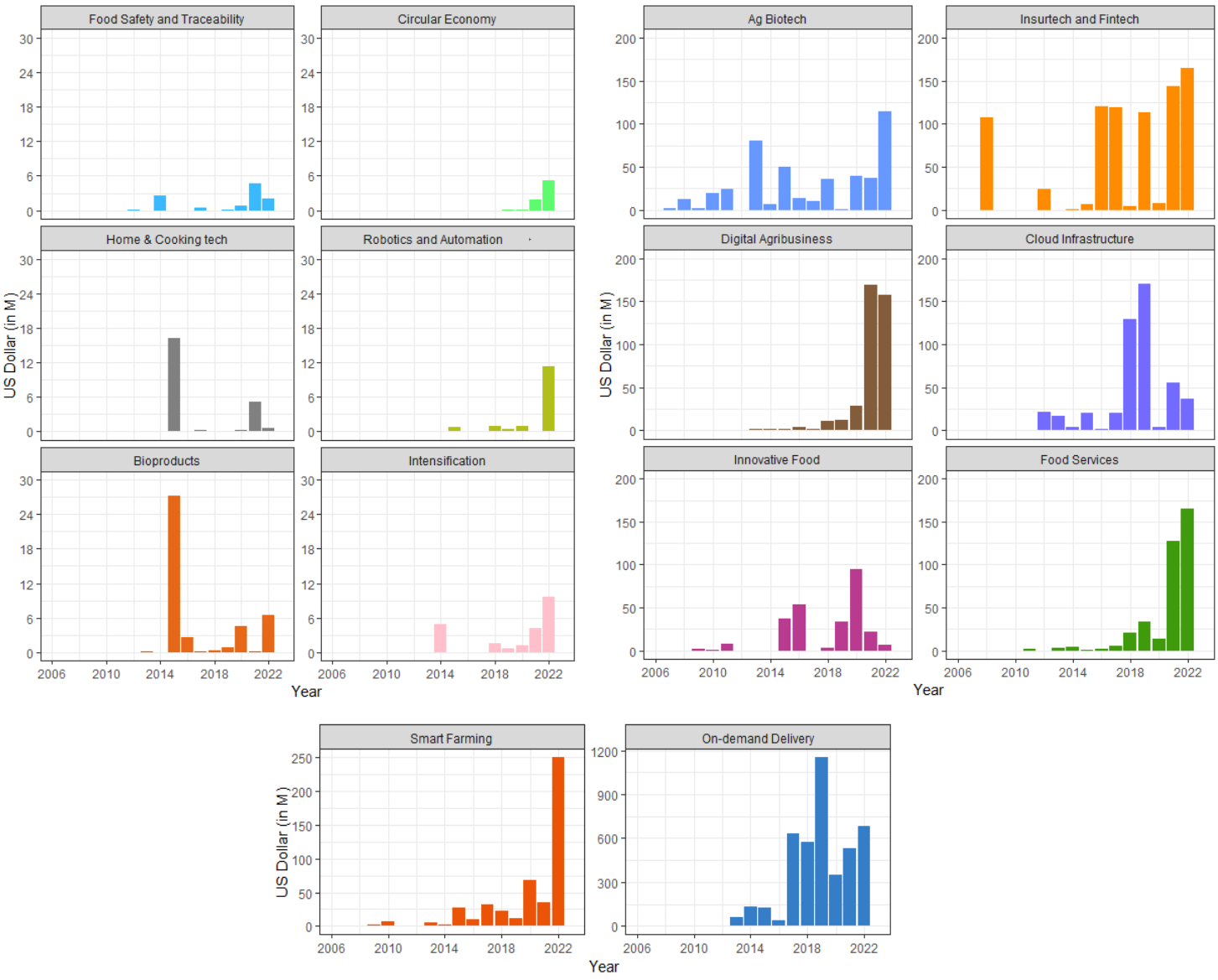


Figure 7: Historical evolution of capital investments in millions of US 2022 constant dollars by technology group and year in South America from 2007 until 2022.

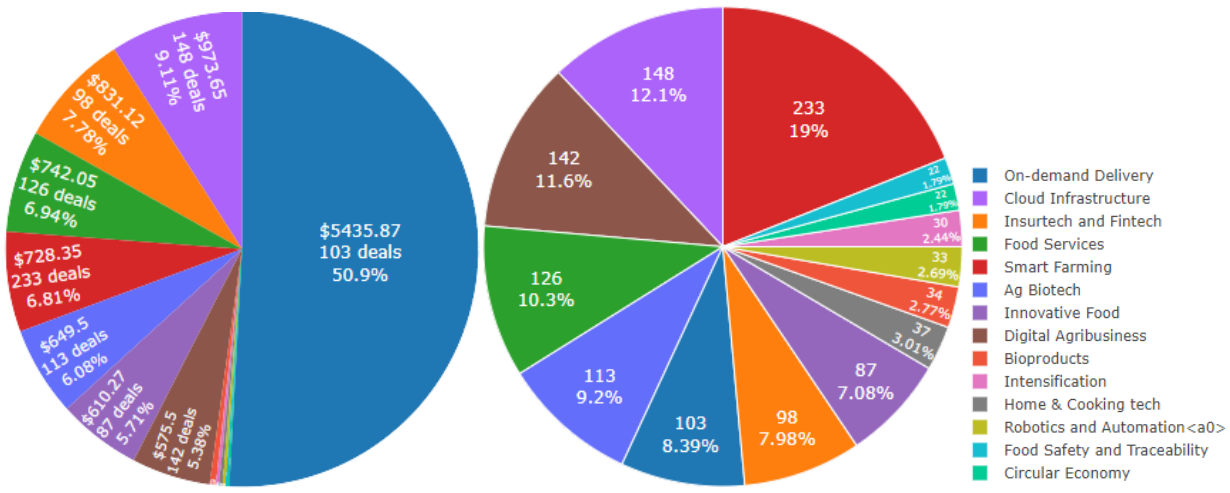


Figure 8: Pie chart that shows the participation of every technology group based on total invested capital (left) and deal volume (right) in agrifood-tech startups in South America from 2007 until 2022.

Food services is the fourth largest technology in terms of raised capital and deal volume with $742 million dollars and 126 deals completed (10.3% of deal volume), respectively. It explains 6.95% of the private capital flows in South America from the last 15 years. It involves the use of various tools and systems to manage and streamline different aspects of the food service industry, including food preparation, inventory management, order processing, purchasing, and delivery. Note that we excluded delivery here including it as a separate technology (on-demand delivery), to fully understand the magnitude of this segment within the industry sector.

Smart Farming and Ag-Biotech had $728 and $650 million dollars in raised capital, respectively. These technologies explain almost 13% of capital inflows into South America and they represent 28.2% of deal volume. Smart farming is the largest segment in deal volume representing 19% of total number of deals conducted in the region. The difference between them is that smart farming refers to all those technologies that allow for the intentional management of information in order to boost efficiency and increase the productivity of production systems. Smart farming is represented by on-farm remote sensing technologies, farm management software, and precision agriculture technologies. On the other hand, Ag-biotech involves all those agribusinesses

that develop technologies that are used as input for agricultural food systems. Here we find gene editing platforms, nano agrochemicals, seed technologies, inoculants, and so on.

Digital agribusiness is a category that has experienced massive growth during the last five years, raising over $575 million dollars in private capital (6% of total capital invested) and completing 142 deals (11.6%). As we discussed previously, market and retail industry segments are growing at an accelerated pace. The digital agribusiness technology group is predominantly composed of digital marketplaces focused on the acquisition of agricultural inputs and services.

Innovative food is primarily represented by highly processed foods such as plant-based food, frozen foods, lab-growth meat, precision fermentation, and mycoproteins. Several of these technologies serve as intermediates for the elaboration of processed food whereas some others can be sold directly to end consumers as ready-to-eat goods. It has raised over $610 million dollars in capital in 87 deals, representing 5.71% of total investments.

Nowadays, there is a globally increasing demand for alternatives to conventional agricultural products that is driven by concerns over environmental sustainability, animal welfare, and healthy diets. This trend also reflects in South America, particularly in countries like Argentina, Brazil, and Uruguay, which are major producers and consumers of meat. This translates to a growing demand for healthy and sustainable food products among consumers in South America, especially in urban areas (C. S. Wee et al., 2014). This created a market opportunity in urban areas for innovative firms that offer alternatives to traditional food products.

Innovative foods deserve mention because beef producers see these technologies as a threat to the future of their businesses. Indeed, when accurate information about meat and meat alternative products is provided to consumers, meat-substitute products might shift no meat consumers towards meat alternatives (Van Loo et al., 2020).

Bioproducts are technological products made with some component of biological or renewable materials. The main examples within the industry are biomaterial, bioenergy, and biofuels. It is a very incipient sector in South America for startups given that most of the biofuel industry is highly concentrated in a few numbers of large corporations. Since 2007, it reported $44 million dollars in capital investments and 34 deals.

Intensification and Robotics are immature sectors in South America in comparison with the numbers reported for developed countries in AgFunder's agtech report (AgFunder, 2023). Intensification refers to all those technologies that increase productivity within the same production surface, such as vertical farming, indoor farming, irrigation systems, etc. Given the inherent abundance of agricultural land and the low production cost when compared to international cost, these technologies meet barriers to adoption and growth at scale. Together they accumulated $48 million in raised capital and represent nearly 5% of deal volume.

Last, we have two technologies that have recently joined the ecosystem: food safety and traceability and circular economy. Together they explain 3.6% of deal volume and have raised $26.7 million dollars in venture capital since 2007. Circular economy technology follows the same pattern as the waste management industry segment, given that both are closely correlated. On the other hand, food safety and traceability can be applied to different industries but is predominantly concentrated in the storage, transport, and distribution segment.

The agrifood-tech ecosystem in South America has undergone significant changes over the past 15 years. If we look closely at the first decade, from 2007 to 2017, we will see predominance of Ag-Biotech and Smart Farming over the other technologies. They concentrate almost 30% of deals volume in the region. Nonetheless, trends have changed during the last five years as a result of the digitalization of the economy that was at the same time boosted by Covid-19. In

consequence, the focus of agrifood-tech investments has shifted towards the end consumer. Technologies such as on-demand delivery apps, food service technologies, and digital marketplaces have received significant funding and are the current leaders in matters of deal volume and capital.

Interestingly, we do not observe significant increase in technology-intensive segments such as robotics, automation, and intensification. According to Viton et al. (2019), the use of highly-intense technologies in South America, which includes robotics and automation, is still limited due to factors such as the high cost of technology, lack of technical expertise, and limited access to credit. The competitiveness of Latin American countries is mostly built on plentiful natural resources and/or low-skilled labor. In consequence, the production structure is poorly diversified, with low value-added and export specialization centered on items with low technological content (OECD Latin America Economic Outlook, 2020).

On the other hand, fintech and cloud infrastructure solutions have become popular in the agrifood-tech ecosystem in recent years, for the reasons mentioned previously. Nonetheless, cloud infrastructure technologies have flourished recently because they are the technologies that provide support to other businesses and activities in the supply chain, enabling the operation of the ecosystem.

4.5 Repeated funding series

Another important metric to understand the performance of local economies and industry segments to the agrifood-tech ecosystem is to look at how many companies were able to raise subsequent funding rounds. 252 out of 547 firms reported two or more funding rounds from 2007 to 2022. Despite accounting for only 46.1% of firms recorded in the dataset, these startups captured 73.3% of investment flows with 811 deals conducted over the study period.

Companies based in Brazil or Argentina lead in repeated funding rounds with 131 and 41 firms, respectively. On average, every firm was able to raise up to three funding rounds, with accelerator/incubator, seed, and series A the most frequent rounds. Brazil alone accounts for 52% of the startups that have reported repeated funding series. Colombia and Chile follow behind with 29 and 28 firms reporting repeated funding rounds, respectively. Both Chile and Colombia average 3.2 funding rounds per agrifood-tech startup. Last, we found Peru and Uruguay each reporting 13 and 6 firms receiving multiple funding rounds.

Among industry groups, primary production is the industry segment with more firms raising repeated funding series. Primary production records 63 firms with 228 funding rounds, accounting for 25% of the set of startups that reported repeated deal series. In addition, primary production shows the best repeated invesments ratio among all industries with 3.6 deals per startup. Market retail and cross cutting innovation follow behind and, individually, each industry segment explain 15% of repeated funding series in South America. Processing and packaging and STD report 30 (11.9%) and 27 (10.7%) firms with subsequent funding series, respectively. In terms of relevance, the remaining industry segments rank as follow: finance (9.5%), inputs (7.14%), consumption (3.5%), and waste (2.4%).

5. Regression Analysis

5.1 Model and explanatory variables

The objective of this section is to explore what factors and intertemporal socioeconomic variables help explain patterns of private agrifood-tech investments in South America from 2007 until 2022. We conducted a regression analysis using a linear model with multiple levels of fixed effects employing the *reghefe* package available in Stata. The linear model is defined as followed:

$$INV_{cts} = \alpha + \beta X_i + \delta_c + \eta_s + \mu_t + \varepsilon_{cst}$$

Where INV_{cts} is the aggregated amount in millions of constant 2022 US dollars invested in agrifood-tech startups in country *c*, year *t*, and value chain stage *s*. X_i are the explanatory variables represented by socio-economic, macroeconomic, and production factor indicators. δ_c is a country fixed effect, η_s is a value chain segment fixed effect, μ_t is a year fixed effect, and ε_{cst} is the error term. Year fixed effects control for the sample average time series 2007-2022 changes. Industry stage fixed effects correspond to the nine categories defined in Section 4 and control for time-invariant, industry-specific factors not included in the set of explanatory variables. Country fixed effect controls for the eight time-invariant, country-specific features common to all industry groups for the countries that reported private capital investments over the study period. The explanatory variables included in the regression analysis are the following:

- Agriculture GDP: Share of agriculture to GDP of country *c* and year *t* in percentage (Source: World Bank).
- Agricultural land (AgLand): Agricultural land of country *c* and year *t* in million hectares (Source: FAOSTAT).

- Agriculture Total-Factor-Productivity (AgTFP): It measures the amount of agricultural output produced from the combined set of land, labor, capital, and material resources employed in farm production. Growth in TFP reflects the overall rate of technical and efficiency change in the sector (Source: USDA).
- Net Capital Stock (NCS): Country's net capital stock in billions of USD. The NCS is estimated through the Perpetual Inventory Method which is a well-established economic model to calculate Net Capital Stocks (NCS) (Source: FAOSTAT).
- Doing Business (DB): The DB score measures an economy's performance with respect to a measure of regulatory best practice across the entire sample of 41 indicators for 10 Doing Business topics. It includes measures on financial credit, investor protection, market structure and openness, legal framework, administration, etc.
- Emerging Market Bond Index (EMBI): The emerging markets bond index (EMBI) tracks the performance of emerging market bonds and was first published by investment bank JP Morgan. Most of the benchmark EMBI index tracks emerging sovereign debt. EMBI reflects the rate at which Governments issue debt denominated in US dollars. For example, an EMBI of 590 points implies an annual interest rate of 5.90% in US dollars denominated debt (Source: J. P. Morgan – BCRD).
- Government Expenditure (GE Annualized government expenditure in agriculture per capita in constant 2022 million US dollars in country c and year t (Source: FAOSTAT).
- Global Innovation Index (GII): The GII measures the grade of innovation of different global economies across 7 dimensions. Parameters for computing the index include 'institutions', 'human capital and research', 'infrastructure', 'market sophistication',

'business sophistication', 'knowledge and technology outputs' and 'create outputs' (Source: World Intellectual Property Organization).

For the agriculture-related variables, we anticipated that changes in AgGDP, AgTFP, and AgLand will have a positive and significant effect on investments given that technically efficient regions with expanding agricultural land would seem more appealing to private capital investors. In the same fashion, we expect that regions more innovative (GII), easy to do business (DB) with, and with larger net capital stock (NCS), will have a positive and significant effect on investments. On the other hand, we expect countries with increasing EMBI and elevated government expenditure (GE) will have a negative effect on capturing investments.

Table 3 provides a summary of descriptive statistics of the variables included in the regression analysis:

	INVcts	**Ag_Land**	**AgTFP**	**AgGDP**	**NCS**	**EMBI**	**GE**	**GII**
N	333	333	259	333	298	333	298	287
Mean	3.31	105.1	98.2	5.63	52.7	7.18	2.44	33.3
Median	2	49.6	98	5.82	34.8	2.62	2.45	3.34
SD	4.005	90.7	7.72	1.56	40.3	30.77	7.84	3.1
Time Series	[2007,2022]	[2007,2022]	[2007,2020]	[2007, 2022]	[2007,2021]	[2007,2022]	[2007,2021]	[2013,2022]

Table 3: Descriptive statistics of the set of socioeconomic, macroeconomic, and production variables included in the regression analysis.

Unfortunately, there is no full times series available for the whole set of explanatory variables included in the study. Thus, we run multiple models to look at the tradeoff between omitted variables bias and loss of explanatory power due to a reduction in degrees of freedom. Further, we seek to understand how consistent the coefficients of explanatory variables are when interacting in more complete models.

5.2 Results

Table 4 shows the outcome of the regression analysis on total private capital investments in 2022 constant US dollars in South America for multiple combinations of country-specific socioeconomic, macroeconomic, and production variables. The table reports the adjusted R^2 degree of freedom, the coefficient estimates for the explanatory and control variables, along with the corresponding p-value on the F-test of the full regression. Table 5 includes a Shapley R^2 decomposition of the ag variables (AgLand, AgGDP, AgTFP), macro variables (GE, GEE, CSN, EMBI), and control variables dummies in order to provide a clearer sense of where most of the variation originates.

We observe that private investment is positively and at least weakly significantly associated with the amount of land in agricultural production but not with the total output share (AgGDP) from that land nor with the overall productivity (AgTFP) of the agricultural system. Given that the country fixed effects control for inter-country differences already, we find that expansion (i.e., within-country change over time) in a country's agricultural land footprint is associated with more capital inflows into the total value chain. Ultimately, considering that land is a finite resource, this finding should encourage governments to study changes in land use associated with private capital investments.

The omitted constant for industry segment is primary production given that it has the largest share contribution in deal volume. Except for STD, there are not meaningful industry differences among industry segments. STD is a big, positive outlier among all the value chain industry segments.

	INVcts_1		INVcts_2		INVcts_3		INVcts_4		INVcts_5		INVcts_6	
Adj. R^2	0.186		0.168		0.113		0.124		0.150		0.147	
Prob > F	0.0000		0.0000		0.0006		0.0011		0.0003		0.0007	
D.F.	333		298		257		257		215		215	
	Coeff	**p-val**	**Coeff**	**p-val**	**Coeff.**	**p-val**	**Coeff.**	**p-val**	**Coeff.**	**p-val**	**Coeff**	**p-val**
Constant	-513.1	0.02	-479.6	0.04	-423.0	0.06	-452.0	0.07	-350.1	0.40	-425.4	0.38
AgLand	4.26	0.03	4.11	0.04	3.86	0.08	3.94	0.07	6.02	0.10	7.02	0.08
AgGDP	3.07	0.73	1.10	0.93	-22.8	0.16	-24.9	0.15	-20.2	0.39	-30.9	0.19
EMBI	0.09	0.77			0.71	0.90					1.22	0.67
GE			-2.85	0.85			-15.7	0.40			-34.4	0.27
AgTFP					1.77	0.20	2.04	0.15	1.43	0.44	1.70	0.37
CSN			0.09	0.91			0.52	0.58			1.11	0.47
GII									-10.3	0.39	-10.2	0.43
Industry												
Consumption	-1.72	0.94	5.07	0.83	6.54	0.79	6.72	0.79	2.16	0.94	2.70	0.93
Cross-cutting Inno.	4.46	0.81	8.50	0.66	3.96	0.84	3.96	0.85	4.70	0.84	4.80	0.84
Finance	17.7	0.44	15.4	0.52	15.1	0.55	15.5	0.54	14.7	0.62	15.7	0.59
Inputs	13.9	0.50	13.36	0.53	14.4	0.51	14.9	0.49	13.2	0.63	13.5	0.62
Market and retail	14.7	0.47	8.83	0.68	-3.14	0.88	-2.41	0.91	-2.87	0.91	-0.89	0.97
Process. & packag.	12.1	0.54	14.5	0.47	13.9	0.51	12.9	0.54	12.3	0.63	10.42	0.68
STD	137.9	0.00	141.1	0.00	125.4	0.00	125.8	0.00	138.6	0.00	139.2	0.00
Waste	-25.7	0.41	-24.1	0.47	5.24	0.91	6.30	0.89	8.81	0.86	9.50	0.85
Country												
Bolivia	277.7	0.19	299.5	0.18			381.2	0.11				
Brazil	-493.4	0.04	-477.7	0.06	-506.9	0.07	-518.3	0.06	-748.8	0.10	-867.8	0.07
Chile	422.4	0.02	410.3	0.05	296.1	0.16	337.8	0.13	577.1	0.15	751.2	0.09
Colombia	339.3	0.01	319.8	0.02	282.2	0.08	289.0	0.08	448.9	0.09	531.7	0.08
Ecuador	437.2	0.06	429.3	0.09	482.7	0.08	515.8	0.06	661.5	0.11	834.5	0.06
Paraguay	429.3	0.07	426.2	0.10	529.1	0.07	555.8	0.06	684.9	0.11	875.1	0.07
Peru	368.8	0.04	353.8	0.06	337.6	0.11	339.5	0.12	534.6	0.12	634.2	0.10
Uruguay	481.2	0.02	464.2	0.05	446.9	0.05	516.1	0.03	684.6	0.08	935.5	0.04
Venezuela	263.4	0.18	261.7	0.19	190.1	0.41	211.9	0.34				
Year												
2008	17.1	0.87	20.2	0.85	8.91	0.93	9.2	0.93				
2009	-36.0	0.73	-33.9	0.74	-42.9	0.67	-39.0	0.70				
2010	-17.7	0.86	-16.8	0.87	-36.2	0.72	-27.3	0.80				
2011	-31.5	0.75	-16.2	080	-49.1	0.62	-37.3	0.72				
2012	-19.0	0.85	-16.6	0.87	-51.2	0.60	-39.4	0.70				
2013	-26.8	0.79	-20.9	0.84	-54.5	0.58	-40.4	0.69				
2014	-26.6	0.79	-21.7	0.83	-54.9	0.57	-42.3	0.68	-9.5	0.78	-12.4	0.72
2015	-26.7	0.79	-22.0	0.82	-67.8	0.50	-57.2	0.57	-26.8	0.46	-34.5	0.40
2016	-25.1	0.80	-18.9	0.85	-45.4	0.64	-32.3	0.74	-28.4	0.59	-27.3	0.65
2017	-0.23	1.99	5.06	0.96	-36.1	0.71	-21.2	0.83	-13.3	0.78	-10.1	0.85
2018	19.2	0.84	25.1	0.80	-17.5	0.86	-4.2	0.96	1.0	0.98	0.94	0.98
2019	17.3	0.86	23.5	0.81	-25.0	0.80	-14.6	0.88	-6.8	0.90	-12.0	0.85
2020	-9.1	0.92	-2.09	0.98	-31.3	0.76	-20.7	0.84	-41.5	0.63	-42.4	0.66
2021	38.8	0.69	47.9	0.63								
2022	31.8	0.74										

Table 4: Summary table of the regression analysis on total private capital investments in 2022 constant US dollar for multiple combinations of country-specific socioeconomic, macroeconomic, and production variables. Prov> F indicates the p-value on the F-test of the full regression, it is followed by the degree of freedom employed in the regression and the estimated coefficients for the explanatory and control variables with their corresponding p-values. STD stands for storage, transport, and distribution.

OLS regression results with decomposition of R^2 (in %)		
Model	**Group Variables**	***R*² decomposition (%)**
INVcts_1	Agriculture	5.25
	Macro	0.61
	Fixed Effects	94.13
INVcts_2	Agriculture	5.77
	Macro	4.19
	Fixed Effects	90.03
INVcts_3	Agriculture	12.05
	Macro	2.22
	Fixed Effects	85.72
INVcts _4	Agriculture	13.18
	Macro	1.52
	Fixed Effects	85.29
INVcts_5	Agriculture	8.98
	Macro	0.50
	Fixed Effects	90.51
INVcts_6	Agriculture	7.15
	Macro	4.98
	Fixed Effects	87.85

Table 5: Shapley R^2 decomposition of the ag variables (AgLand, AgGDP, AgTFP), macro variables (GE, GII, CSN, EMBI), and fixed effect control variables dummies employed in the multiple regression models.

Much of the variation is at the country level, with Brazil getting less investment than one would predict (largely due to its vast land in agriculture) and most other countries getting more than one would predict relative to the Argentina base case. Macroeconomic and macrofinancial attributes such as CSN, EMBI, GE and GII have effectively no explanatory power. The big run-ups in private investment over the time period are likely driven by fundamentals, not by time trends independent of the explanatory variables. According to table 4, the explanatory variables included in the analysis can explain up to 15% of the variation observed in the analysis. Even with the wide dimensions covered by the explanatory variables, most variation in private investment remains unexplained, likely due to firm-level factors, and not attributable to the macro-scale factors we included in this study.

6. Accelerators and barriers to technology adoption and uptake to scale

In the last decade, agrifood-tech has emerged as one of the key economic sectors in South America, driven by the inflow of private capital investments into agrifood-tech startups. Certain industries and agrifood technologies have found fertile soil in South America to expand their markets, capturing large inflows of private capital, and benefiting from key *accelerators* available in the region. However, the South American agrifood-tech ecosystem also shows *barriers* to the continuous formation of capital and to the adoption and uptake to scale of agrifood technologies and innovations. In this section, and based on findings from sections 5 and 6, literature reviews, and discussions with industry experts, we expose the major accelerators and barriers to the development of the agrifood-tech ecosystem in South America.

Investing in agrifood-tech startups is different from investing in publicly traded companies, sovereign bonds, or any other financial assets. Agrifoods startups are typically early-stage companies that aim to develop innovative solutions to address unmet market needs, and they often operate in a rapidly changing, highly regulated, and competitive environment. Startups are often pre-revenue or have limited revenue, and have limited financial data available, making it challenging to assess their future prospects accurately using traditional financial models such as discounted cash-flow models or capital asset pricing models. Thus, investors commonly value startups based on (i) the innovativeness of their technology, (ii) their business model, (iii) the size and potential growth of the market target, (iv) the entrepreneurial team, and (v) market validation.

Our regression model proves that most macroeconomic and financial indicators are unable to explain the variability in investment flows, strongly suggesting the central importance of these fundamentals. Common macroeconomic and macrofinancial indicators such as inflation, net capital, and government expenditure that succeed in explaining variability in foreign domestic

investments in South America (Owusu-Nantwi, 2019), fail when applied to agrifood-tech investments. However, agricultural land succeed is positively and significantly associated with private agrifood-tech investment flows. We can associate countries with larger agricultural land with countries with larger markets for agricultural technologies, perhaps especially in primary production, on which a plurality of deals have focused.

Several technologies reported in section 4 such as smart farming, digital agribusiness, on-demand delivery, and fintech will directly benefit from digitalization, in its various dimensions (economy, social, education). In 2022, the OECD released its biannual economic report which focused on the digital transformation of the Latin American economy. It states the strengths and challenges that the region is facing in terms of the digitalization of its economy at the macro and microeconomic levels. The report highlights that the region is in an excellent position to take advantage of the digital transformation, primarily because of increased access to the internet and ICT devices (OECD, 2022). Nonetheless, it requires the promotion of its enabling infrastructure such as connectivity, with a focus on rural areas, and digital skills for all participants of the economy. In addition, it requires to work on its legal frameworks that provide solid bases for innovation and investments.

Higher education plays a key role in driving innovation. Studies have shown that there is a positive correlation between the amount people holding graduate studies and the degree of innovation of a country measured through the number of patents and the contribution of skilled human capital to total-factor-productivity (G. Chellaraj et al., 2005; D. Marotta, 2007). However, despite an abundance of degree and postgraduate programs, South America lacks high-level training programs (mostly PhDs), negatively impacting research and development (R&D). In South America, there are 50 new doctorates awarded per million inhabitants annually, while in the

US this number is three times higher, 150 per million inhabitants (CONACyT, 2010). Investing in necessary skills and closing the gap with technological frontier countries will be critical for South America to harness digital technologies.

Governance plays a crucial role in coordinating innovation efforts between and within countries. During the last decade, four of the top five countries leading agrifood-tech investments in South America have deployed governmental digital transformation programs. These initiatives include the National Internet of Things Plan of Brazil, the Uruguayan Digital Manufacturing Laboratory, and the Fourth Industrial Revolution Centre of Colombia, which is run by the Ruta N Corporation in Medellin. Argentina has recently announced its Digital Transformation Program for small and medium enterprises (SMEs). It would be worth exploring the impact of this program on transforming regional economies and if it exists a correlation between these programs and the formation of capital.

It results paramount to ensure a digital transformation for all, prioritizing those SMEs and disadvantaged subpopulations are able to access all the benefits of digitalization (OECD, 2022). The accelerated pace of digitalization may accentuate disparities between socioeconomic groups. Thus, governments must ensure equitable access to technologies and train their population on digital tools to make the best of this revolution.

Despite promising investment trends, the agrifood-tech ecosystem in South America still faces some challenges. For instance, the lack of access to funding and the limited development of capital markets in most of South American countries can hinder the growth of startups and limit their impact. Previous studies have shown that, historically, emerging market funds have underperformed market averages. Some of the main reasons are low standards of corporate governance in terms of the quality of information required to make investment decisions and

monitor performance once investments have been made; the weakness of legal systems in enforcing contracts and protecting all classes of investors; and the inability of domestic equity markets to offer a reasonable prospect of exit through the IPO market (R. Leeds & J. Sunderland, 2003).

A strong domestic capital market stimulates investments in innovation, gives governments and businesses access to long-term financing in local currency, and fosters sustainable growth with more employment opportunities. This is both a barrier and an opportunity for the expansion of the agrifood-tech ecosystem in South America. Market capitalization as a percentage of GDP in South America averages just 21.1%, which is low when compared to the capitalization of developed domestic markets where capitalization rates often surpass total domestic GDP (CEIC data, 2022). Brazil has the most developed and active capital market in the region, with a market capitalization of $770 billion US dollars, which represents 75% of the total equity in South America. Out of the 56 IPOs completed in 2021 in South America, Brazil accounted for all but one (with the other in Uruguay)(White & Case, 2022). If we look at the major countries driving capital investments in South America we will see that there is a general process of delisting observed for Chile, Colombia, and Argentina (Uruguay's stock market capitalization is less than 2% of GDP). In Colombia and Argentina, the last IPOs in their domestic markets date from 2012 and 2010, respectively. This sets a massive barrier to the development of the ecosystem. Developing domestic markets is paramount in order to help regional economies to capture larger deals, avoiding domestic startups seeking foreign markets to list their businesses.

In addition, fund managers interviewed emphasized the lack of sophisticated investors in the South American agrifood-tech space. Investing in agrifood-tech is different than investing in most common technology verticals for a number of reasons. First, agriculture has a long investing

horizon. Agriculture is inherently a long-term industry due to the nature of crop cycles and the time required for plants to grow. Unlike sectors with rapid product development or technology adoption, agricultural investments often require patient capital. Sophisticated VC investors in agriculture understand the extended timelines involved and have the financial capacity to sustain investments over extended periods. Many, perhaps most, VC and other investors do not.

Second, investing in agrifood-tech demands technical expertise and industry knowledge. VC investors in agriculture need to have a wide understanding of the various scientific fields involved in the primary production and post-harvest processing and marketing of agricultural products. They must be able to evaluate and assess market demand, distribution networks, and regulatory environments. Having sophisticated investors with specialized knowledge allows for more informed decision-making and effective support to portfolio companies. Such expertise is relatively scarce in the investing community.

Third and last, agrifood-tech is capital-intensive. Agriculture often requires substantial upfront investments in land, equipment, infrastructure, and working capital. Developing and scaling agrifood-tech projects can be capital-intensive, especially in emerging markets where agricultural infrastructure may be lacking. This is particularly true for the storage, transport, and distribution segment as we discussed in the previous section. Sophisticated VC investors with access to sufficient capital and the ability to structure complex financial arrangements can provide the necessary funding to support the growth and expansion of agricultural enterprises.

Lastly, there are two additional key areas where South America governments should focus efforts to promote its agrifood-tech innovation ecosystem. First, South America's governments should facilitate interactions between the private sector, governments, and research institutions in order to boost domestic R+D and innovation. This includes creating the financial vehicles

necessary to finance R+D projects that focus on the delivery of new products and services into the market. By establishing partnerships and providing financial incentives, governments can help bridge the resource gap, enabling research institutions and businesses to pursue innovative projects. For example, the Brazilian Agricultural Research Corporation (EMBRAPA) has collaborated with private companies to develop and commercialize genetically modified crops (Parente et al., 2021). Further, international organizations like FONTAGRO have taken this role and actively fund research projects in South America in order to generate knowledge that ultimately can be useful for decision-making or for the development of new technologies.

Lastly, governments should support the enabling environment through infrastructure investments and policies that encourage the adoption and uptake of agricultural technologies. Empirical studies have shown that risk exposure and risk preferences are among the main drivers of the timing and extent of agrifood technology adoption (Marra et al. 2003; Liu 2013). At the farm level, there are three variables that have to be taken into account to foster technology uptake: (i) opportunity cost, (ii) risk, and (iii) the possibility to postpone adoption (Spiegel et al., 2021).

Governments and private institutions can intervene in this area by providing safety for technology testing at the farm and industry levels. For example, the government of Israel deployed a technology uptake program that finances up to 50% of the cost of running a pilot test at farm level, the other 50% is incurred by the farmer (Israel Innovation Authority, 2023). The government expects that this program will ultimately increase technology uptake, and consequently boost productivity leading to higher agriculture yields. As the output increases, the amount of money collected through taxes increases as well, which ends up paying off the cost of running the program.

Overall, the adoption and uptake of agricultural technology at scale in South America is influenced by a complex set of factors, including government policies, sophisticated investors, public-private partnerships, access to financing, infrastructure, and knowledge and skills. The investment trends suggest that the ecosystem has the potential to continue growing and transforming the food industry in the region, but challenges related to funding, education, technology cost, and regulation will need to be addressed to fully realize this potential. Addressing these challenges will be crucial to unlocking the full potential of the agrifood-tech sector in South America. Investors can play a crucial role in this game, but they must also be aware of the challenges and barriers that may limit their impact.

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Annex A: Technology and industry classification (explained).

Category		Description
Industry Segments		
1.	Cross-cutting innovations	Innovation supporting the enabling environment (e.g., regulatory, cloud-infrastructure, educational, cultural, etc.)
2.	Food system Inputs	Fertilizers, labor, capital, energy, etc.
3.	Finance	Fintech, insuretch, novel payment platforms, etc.
4.	Primary production	Crop and animal production, cellular agriculture, aquaculture, etc.
5.	Processing and packaging	Novel packaging materials, improved food processing, novel foods.
6.	Storage, Transport and distribution	Improvements in logistics, farm2consumer platforms, cold chains, dehydration, on-demand delivery.
7.	Markets and retail	Supermarket innovations, ag marketplaces, food labeling and marketing.
8.	Consumption	Personal health, new kitchen devices, coocking-tech, etc.
9.	Waste	Waste processing and repurposing, circularity, etc.
Technology groups		
1.	Ag Biotech	Inputs for the primary production of fagriculture products.
2.	Bioproducts	Bioproducts are products made with some component of biological or renewable materials.
4.	Circular Economy	Recycling, Reuse, and/or Reallocation of resources.
5.	Cloud Infrastructure	Cloud infrastructure that back-up the operation of the agrifood ecosystem.
6.	Digital Agribusiness	Agriculture business with a high digital component. Example: Farm input retail and markets, commodities markets, professional services, etc.
7.	Food Safety and traceability	Food safety & traceability tech, logistics & transport.
8.	Food Services	Delivery-apps, on-demand apps, and all technologies that facilitate the consumption of agriculture/food goods.
9.	Home & Cooking tech	Smart kitchen appliances, nutrition technologies, cooking apps
10.	Innovative Food	Cultured meat, novel ingredients, plant-based proteins
11.	Insurtech and Fintech	Financial solutions for the agrifood industry. Blockchain, credits, payment solutions, etc.
12.	Intensification	Technologies that allows higher outputs within the same production surface. Indoor farming, Vertical farming, irrigation systems, aquaculture, insect & algae production
13.	Robotics and Automation	Drones, robots, Shelf-stacking robots, 3D food printers, POS systems,
14.	Smart Farming	Intentional management of information and communication tools to boost productivity or to improve efficiencies of productive process (quality or quantity).