Inter-American Development Bank

Monitoring and assesing the impact of Supply Chain 4.0 in Latin America

Framework, application to agribusiness and policy discussions

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TABLE OF CONTENTS

CHAPTER 1 2
Introduction

CHAPTER 2 6
Supply Chain Management and Industry 4.0

CHAPTER 3 14
Public Policy & Supply Chain Management

CHAPTER 4 16
A Latam Perspective: an illustrative application to Agribusiness

CHAPTER 5 27
Conclusion and future directions

Bibliography 29

APPENDIX I 32
Micro trend initiatives, startups and companies

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CHAPTER 1

Introduction

A number of authors have asserted that world has already entered or is about to enter a new industrial revolution. This (possible or real) new revolution is typically called “Industry 4.0”, a term first introduced by Kagermann, Lukas, and Wahlster (2011) and later popularized by a number of practitioners and institutions (Schwab 2016; Basco et al., n.d.; PwC 2016). The “4.0” is a reference to the previous three industrial revolutions. The first such revolution gave birth to the expression “Industrial Revolution”, coined by the historian Arnold Toynbee (1852–83), and took place in the late 18th to early 19th century. This first industrial revolution was triggered in England by the construction of railroads and the invention of the steam engine. The second industrial revolution took place in the late 19th and early 20th century, and was characterized by a transition to mass production within many industries in Europe, the United Sates and Japan. This second revolution was perhaps best exemplified by the manufacturing techniques used by Henry Ford which led to the creation of the Ford Motor Company in 1903. The third industrial revolution spanned the second half of the 20th century, and is typically called the “digital revolution.” This third revolution is characterized by the impact of semiconductors, computers and the internet.

Because Industry 4.0 is a new, ongoing phenomena it is broadly defined. The idea behind Industry 4.0, and even the expression itself came from practice and what is called “grey literature” (initiated

by a German government document presented in the Hannover fair). Because the phrase emerged from practice, the academic literature has failed to fully account for the phenomena. Some academic examinations do exist, for a literature review of industry 4.0, see (Liao et al. 2017; Lu 2017; Hofmann and Rüsch 2017; Trappey et al. 2017). Despite some valiant efforts, because Industry 4.0 is an emergent phenomena, scientific publications have struggled to keep up[1]. This paper will focus more on the state of practice, rather than examining the current academic literature. Some authors have attempted to link industry 4.0 with specific technological innovations. However, it is crucial that any speculative definition remain broad, as it is unclear which technologies, or which technologies in combination will actually spur a dramatic change. Nevertheless, for the purposes of this paper, some categorization is necessary. Such categorization can guide analysis, and more importantly help to establish boundaries as it will be impossible to conduct a comprehensive examiniation of the theoretical impact of each new technology. One of the earliest works that considered the emergence of industry 4.0 was (Schwab 2016). According to (Schwab 2016) there are three main areas of potential impact: (i) Physical; (ii) Information; and (iii) Biological. As examples of physical innovations, Schwab mentions 3D Printing (Ernst & Young 2016), robotics (Bonkenburt 2016; Decentralization 2015), autonomous vehicles (Heutger 2014; DHL 2014), and others. As examples of biological innovations, the author discussed bioproduction and industrial biotechnology (OECD 2016). Finally, in the information sector, the author called attention to artificial intelligence (McKinsey Global Institute 2018) and internet of things (Macaulay, Buckalew, and Chung 2015). This list of potential areas of impact is helpful, but is not sufficient for the study of industry 4.0. Innovations rarely happen in a vaccuum; and more often are part of an ongoing trend which (i) helps define what problems innovators should focus on; and (ii) aids in the adoption and diffussion of the innovations that tackle the same problems. Therefore, most literature around Industry 4.0 starts with a list of revolutionary innovations and descriptions of a limited number of macro and micro trends (Schwab 2016). Furthermore, the efforts of academics to predict impact have also fallen short because of the inability of any individual actor to accurately forecast technological change. Because of this, most authors simply make general observations about potential areas of impact, and (sometimes) provide generalized "order of magnitude" estimates. In general, these authors believe the 4th revolution will spur change in two big areas: productivity and jobs.

[1] There are several reasons for this including the time academic works take to get published, the tendency to favor quantitative work within the academy, and because it is difficult to measure theoretical impacts of technologies that have not yet been invented.

Any so-called "industrial revolution" should achieve dramatic increases in productivity. Despite advances in particular fields a generalized increase in productivity has failed to emerge, in fact productivity declined with the turn of the century in many of the most industrialized and advanced nations (Bureau of Labor Statistics 2018; Fernald and Wang 2015). At the same time, there are concerns about Industry 4.0 creating massive job losses (Frey and Osborne 2013). It is not clear that these job losses will take place, however. For example, both US and German unemployment rates are currently between 3-4%, among the lowest ever recorded (Trading Economics 2018a, 2018b). In any case, not all experts predict net job losses. For example, a McKinsey Global Institute report estimated that while job losses could represent up to 15 % of the global work force, newly created jobs will represent between 21 and 33 % of the global work force, more than compensating for losses (McKinsey Global Institute 2018). Even though McKinsey estimates that an average of 3% of occupations will disappear, they estimate that the number of jobs changed will be greater than the total number of jobs created or lost (McKinsey Global Institute 2018). This will require new skills for a large number of workers, which indicates the necessity of education/training to prepare the world´s population for the changes to come. Just as there will be winners and losers within the workforce, revolutions tend to redefine the wealth and prosperity of entire nations (Lange, Wodon, and Carey 2018). The countries and regions best prepared and fastest to react to technological change will be the economic winners of the future.

In summary, although few authors doubt that, at some point, a new revolution will come, the evidence shows that its broad impact has not yet arrived. The fact that the revolution is still forthcoming is good news for developing nations in general and LatAm in particular. LatAm still has a chance to fully prepare for Industry 4.0, reap its benefits and mitigate its risks, even potentially leaping over development stages into more advanced ones. Taking full advantage of Industry 4.0 will require vigilance, monitoring the horizon for coming trends and innovations to give government, companies and society time to react. This paper can aid the preparation process. This paper highlights trends and innovations likely to impact Latin America in the context of the coming 4th industrial revolution, and to attempt to assess their (collective) impact. This analysis is crucial for the region's future, but it is also essential to narrow our focus, as an analysis of all possible technological innovation is impossible. To limit the scope, this research proposes a focus on the most important and relevant industries in the region. For the purpose of clarity, this research will focus on two important aspects of theoretical development: supply chain development and development in agribusiness. Even though this scope is limited, the general approach to analysis demonstrated here can be applied to Value Chains in general and other industries as well.

In Section 2, the paper examines how Industry 4.0 can impact supply chains at the global level and proposes a framework for this assessment. In Section 3, the link between Supply Chain Management and public policy is scrutinized. Section 4 attempts to apply the framework to LatAm, using Agribusiness as an example. Section 4 is divided into four parts: (i) a general introduction to the ongoing revolution in agribusiness; (ii) macro and micro trends; (iii) an initial impact estimation; and (iv) policy discussions around the adoption of SC 4.0. Section 5 concludes the paper with conclusions, directions for further research and ongoing monitoring.

CHAPTER 2

Supply Chain Management and Industry 4.0

Supply Chain Management is the art and science of managing physical, financial and information flows, all the way from the production of raw materials to end consumers. Two ongoing trends threaten this discipline: (i) globalization requires managing flows more complex and geographically dispersed; and (ii) changes in information technology are allowing greater coordination and analytical assessments. On top of these ongoing trends, Industry 4.0 will change where people produce as much as what and how they produce. As a consequence, a number of leading authors and institutions such as McKinsey and the World Economic Forum have given a call to arms to the supply chain community to get involved in what they call *Supply Chain 4.0* (Alicke, Rexhausen, and Seyfert 2017a; World Economic Forum 2017). As a result, logistics and supply chain companies have also paid attention to the topic. In particular, the Deutsche Post DHL Group, the largest logistics and mail company in the world, with over 500,000 employees and over 60 billion Euros in revenues, has decided to join the conversation (Deutsche Post DHL Group 2018; DHL 2016; Gina Chung et al. 2018). Just as with its Industry 4.0 counterparts, the Supply Chain 4.0 community has provided (i) a classification of innovations and trends; (ii) a list of innovations, macro and micro trends; and (iii) some preliminary impact assessments.

There have been academic research projects on individual (potential) elements of SC 4.0, such as the Internet of Things (Ben-Daya, Hassini, and Bahroun 2017), 3D printing (Rogers, Baricz, and Pawar 2016) and big data (Wang et al. 2016; Govindan et al. 2018). However, the number of academic publications specifically devoted to SC 4.0 is limited. A recent literature review can be found in the paranthetical source (Kuznaz, Pfohl, and Yahsi 2015). IDB itself is beginning to produce literature on the topic of SC 4.0. For example, (Calatayud 2017) discusses how SC 4.0 might improve risk management on a global scale.

2.1 Classification of innovations and trends

The Deutsche Post DHL Group, in its Logistics Trend Radar publication (Gina Chung et al. 2018; DHL 2016), classified innovations in two main groups: technology trends and social & business trends. Technology trends are those trends emerging from technological advances that create whole new business or products, such as self-driven vehicles or artificial intelligence, or incremental developments like low cost sensor solutions. Social & business trends emerge from changing consumer behavior and expectations, from the evolution of business practices and their societal adoption and adoption of new alternatives to coordinate the way we utilize resources. For example, omni-channel logistics and the sharing economy are both instances of social & business trends. DHL also classified innovations according to their expected level of impact using a qualitative scale ranging from low (incremental impact) to high (potentially disruptive impact). Finally, innovations were classified based on the expected time it will take for each innovation to be relevant, separating the short and medium-term trends (less than 5 years) from the long-term trends (more than 5 years). DHL uses a “radar” analogy, and proceeds to classify innovations according using this language. Some trends are right ahead of a given industry, some are distant but lie in the current developmental path, while others require a different trajectory to be accessed.

The World Economic Forum produced a white paper on several main technological innovations that could form the basis of Industry 4.0 and analysed their effects on value chains, logistics, the enviroment, and jobs (World Economic Forum 2017). The authors then matched these technological innovations with broader trends. For instance, the paper linked 3D Printing, a purely technological innovation, with Distributed Manufacturing, its counterpart trend in the value chain. Innovations were also analysed from the perspective of logistics services, environmental impact, job creation and destruction, and general value chain. In essence, innovations were considered in the context of different stakeholders or trends/areas of impact.

In an article devoted to the consumer goods industry (Alicke, Rexhausen, and Seyfert 2017a), McKinsey took a distinct approach and focused its analysis on improvement levers: applications of new technology to a particular industry´s supply chain management processes. These levers, such as predictive analytics in demand planning or autonomous and smart vehicles were classified among six business value drivers: planning, physical flow, performance management, order management, collaboration and supply chain strategy. These drivers, in turn, support the goals of improved agility, better service, reduced capital and reduced cost. McKinsey's classification of innovations is highly business-focused, mapping them to the value they can create for companies in consumer goods. McKinsey´s article exemplifies how focusing on a given industry (i.e., consumer goods) and discipline (i.e., supply chain management) allows a more concrete set of predictions and analysis.

The following framework is not comprehensive, but focuses on three trends that are complementary in exploring SC 4.0 innovations.

2.2 List of Micro and Macro trends

Based on the aforementioned papers from the WEF, DHL and McKinsey, this paper proposes a consolidated list of trends and innovations that form a common core. This common core is composed of the following trends:

Trend	WEF	DHL	McKinsey[2]
Additive Manufacturing	Additive Manufacturing Distributed Manufacturing	3D Printing	3D Printing
Artifical Intelligence	Artificial Intelligence	Artificial Intelligence	Automation of knowledge work Automated root cause analysis (fueled by AI)
Autonomous Vehicles	Autonomous Vehicles Driverless transport systems	Self-Driving Vehicles	Autonomous and Smart Vehicles

2 Comparisons between these three sources should take into account that McKinsey's paper focuses on consumer goods while the WEF and DHL papers are not industry specific and broader in scope. It is also important to note that, while (Alicke, Rexhausen, and Seyfert 2017b) do not mention certain specific trends in the context of their article on SC 4.0 in the consumer goods industry, this is not equivalent to saying that McKinsey at large is not focusing on these trends. McKinsey is a global, diverse firm with thousands of people that may be working (and writing about) any given topic.

Trend	WEF	DHL	McKinsey[2]
Big Data and Predictive Analytics	Predictive Analytics Predictive Maintenance Analysis of data from social media platforms	Big Data Analytics	Predictive Analytics in Demand Planning Advanced Profit Optimization Smart logistics planning algorithms
Cloud Logistics	New collaboration models	Cloud Logistics	Suppy Chain Cloud
Robotics and Automation	Advanced Robotics Pick by Light Robots	Robotics & Automation	Automation of Warehousing: robotics
Wearables and Bionic Enhancements	Enterprise Wearables Pick by Voice	Bionic Enhancement	Human-machine interfaces
End-to-end connectivity and visibility	Cross-company machine-to-machine communication	-	End-to-end/multitier connectivity Online transparency and real-time exception handling Reliable online order monitoring
Augmented Reality	Augmented Reality Pick by vision	Augmented Reality	-
Batch size one	Lot Size 1/Mass Customization	Batch size one	-
Blockchain	Blockchain	Blockchain	-
Fair & Responsible Logistics	“Glocalization” and near-shoring	Fair & Responsible Logistics Green Energy Logistics	-

Trend	WEF	DHL	McKinsey[2]
IoT – Internet of Things	IoT - Internet of Things	IoT - Internet of Things Next-generation Wireless Low-cost Sensor Solutions	-
Logistics Orchestration	Orchestration by 3PL/4PL	Supergrid Logistics	-
Unmanned Aerial Vehicles	Drones	Unmanned Aerial Vehicles	-

In addition to these core trends, each paper contained analysis of a few potential emerging trends that were not mentioned in the other papers:

WEF	
Co-Creation and Open Innovation	Open platforms for cooperation on innovation and R&D, connecting companies needs to experts and crowdsourcing contributors
DHL	
Connected Life	Secured access to consumers' ecosystem of connected devices will offer many opportunities for logistics optimization and innovative services
Digital Work	Companies need to develop new ways to train and prepare the workforce to continuously interact with robots and software (virtual bots) in the working environment
Fresh Chain	Increasing online shopping of goods that require shippments with temperature integrity will pose new challenges to companies
Grey Power Logistics	An aging population will demand new levels of logistics services integrated with healthcare
Logistics Marketplaces	The emergence of digital brokerage platforms that can match demand with supply of logistcs services
Omni-channel logistics	The next generation of retail operations must support visibility and transparent interactions between all channels
Servitization	New business models will emerge by replacing traditional manufacturing product-based strategies with a service-based one, creating closer links with customers
Sharing Economy	The shift from ownership to asset sharing models, that is currently advancing in several domains including logistics
Smart Containerization	The need for volume flexibility and an increasing time and cost pressure will demand new container formats and processes, particularly in urban logistics
Tube Logistics	The use of existing and new tube infrastructure for cargo transportation is attracting interest
Virtual Reality & Digital Twins	The possibility of designing, evaluating and simulating environments in virtual reality together with a digital simulation of current operations can unlock new SC optimization opportunities

McKinsey	
Closed-loop Planning Scenario Planning Real-time replanning	Powered by Automation, Artificial Intelligence and Predictive Analytics planning cycles will be shortened to a near continous timeframe making it possible to achieve real time replanning, scenario analysis and closed-loop planning
Digital performance management	The availability of real time data will enable SC visibility as well as digital performance management powered by realtime dashboards capable of drilling down on granular operation indicators
Micro-segmentation Dynamic network configuration	Companies will need to respond even more quickly to an increasing demand for mass customized products – Big Data and Predictive Analytics will power companies to create hundreds of micro supply chain segments to maximize flexibility while minimizing cost and inventory
No-touch order processing	Automation and real time replanning combined with cloudplatforms can enable continuous integration between available-to-promise (ATP) process and the order processing system, improving reliability and customer experience

2.3 Impact Estimation

Preliminary impact estimations in SC have mostly focused on productivity, profitability and return on capital gains. There are also some estimates of impact in an area that is particularly relevant to this discipline: CO2 emissions. Little research on SC has focused on job destruction and creation beyond the broadest analysis. Clearly, not all industries will be impacted in the same way. As a result, impact estimates are conducted by sector/industry.

Quantitative Impact Estimates

The following table summarizes quantitative impact estimates provided by McKinsey and the World Economic Forum:

McKinsey	WEF
For the **Consumer Goods industry**: • Up to 30% lower transport and warehousing costs • Up to 80% lower SC admin costs • Up to 75% fewer lost sales • Up to 75% decrease in inventories	• Up to 25% reduced CO2 emissions, based on company-specific studies on process digitization, improved technical systems sensoring and machines data analytics & predictive maintenance • Reductions can be much higher with 3D printing

Qualitative Impact Estimates

DHL did not estimate quantitative impact but rather focused on qualitative estimates per trend, indicating the industries potentially impacted by each. The following table sumarizes the impact estimates by industry:

Industry	# of High Impact trends			Trend Examples
	< 5 Years	> 5 Years	Total	
Automotive & Mobility	4	8	12	Self-Driving Vehicles, Logistics Marketplaces
Engineering & Manufacturing	4	7	11	3D Printing, Internet of Things
Technology	4	7	11	Artificial Intelligence, Cloud Logistics
Retail & Consumer	3	7	10	Omni-channel Logistics, Robotics & Automation
Life Sciences & Healthcare	2	7	9	Big Data Analytics, Digital Work
Energy	2	6	8	Green Energy Logistics, Supergrid Logistics

CHAPTER 3

Public Policy & Supply Chain Management

Because Supply Chain Management is an activity primarily conducted by private companies with the purpose of improving their profits and returns, the link between supply chain management and public policy is not always clear. There are exceptions in cases where the government provides an overarching industrial policy or incentives and regulations for specific industries. Nevertheless, there is a direct link between efficient supply chain management and the productivity issue discussed above, and as a result, it is of great interest to policymakers. Public policy makers would be well-served to examine how public policies can be tailored to fit the needs of different supply chains. Some governments have already made positive steps towards this end.

Canada has led in this area, launching the Gateways and Corridors Initiative (GCI). The GCI includes a set of investment and policy measures focused on facilitating global supply chains between Canada and Asia through strategic transportation infrastructure projects. These infrastructure projects will reduce bottlenecks and improve trade flows in and out of Canada's west coast. The objective of the initiative as stated by the Canadian government is:

Canada's Gateways and Trade Corridors comprise the transportation infrastructure, systems, operations, technology, regulatory and policies related to the marine, road, rail, and air modes supporting freight and passenger flows of national significance for international commerce. As a trading nation, Canada aims to improve the country's competitiveness in the world market leveraging the Strategic Gateways and Trade Corridors approach.

In an effort to propose a framework for public policy decisions, (Barbero, 2009) outlines four dimensions where public policies interact directly with supply chains and particularly its freight logistics functions: (i) transportation infrastructure, including the public investment and operation of the different modes (roads, ports, airports, rail, waterways) (ii) services and regulations provided by the state, including customs, health inspections and others, (iii) regulations of services provided by the private sector, including concessions, management contracts, and the regulation of maritime and air services, technologies and others; and (iv) support to private sector development.

As examined in the previous section, the core of SC 4.0 is the management of technologies and innovation along the supply chain. Both technological management and supply chain management are directly impacted by the public policy areas described above.

Photo by Scott Goodwill

CHAPTER 4

A Latam Perspective: an illustrative application to Agribusiness

In this section, this paper introduces a framework to asses, monitor and react to the evolving Supply Chain 4.0 within the context of Latin America. The proposed framework contains 3 main steps: **(i) identify macro and micro trends; (ii) perform a high level impact estimation; and (iii) outline potential policy actions.**

To maximize the prospect of predicting relevant tecnologies/ trends, improve the quality of estimates and the relevance of recommendations, this framework is applied on an industry by industry basis. As an initial example, this paper will focus on the industries and sectors which are most vital to the LatAm economy overall. No matter what methodology is used for an impact/relevance assesment, agribusiness is undeniably a vital sector for LatAm. Below, the proposed framework is applied to agribusiness in LatAm.

4.1 The coming revolution in agribusiness and how it relates to LatAm

Agribusiness is one of the most important sectors in Latin America. For many countries in the region, agribusiness also represents the top export. For example, according to data from the Brazilian Institute of Geography and Statistics (IBGE) and the

National Institute of Statistics and Censuses of Argentina (INDEC), agribusiness in Brazil and Argentina amounted to US$135 billion in 2016 (IBGE 2018; INDEC 2018). LatAm is the global leader in exports of bananas (65% of total), soybean oil (62%), raw sugar (49%), soybeans (48%) and coffee (38%), and the second largest world exporter of corn (32%) and cocoa beans (12%), according to 2016 data provided by the MIT Observatory of Economic Complexity (Simoes 2018).

Given its importance, IDB has already developed knowledge related to Industry 4.0 and SC 4.0 in the region. As examples, see (Inter American Development Bank 2018a) for a discussion about agrotech in Argentina, and (Inter American Development Bank 2018b) for a study on and recommendations for the milk production sector in Paraguay. There is also an excellent region-wide study focused on how to finance new digital tecnologies in agribusiness (Fernandez Diez and Fernandini Puga 2018).

4.2 Identifying Macro and Micro Trends

The world´s population growth rate is declining (Melorose, Perroy, and Careas 2015), and at the same time, both the total number of people and the percentage of the population below the poverty line are also declining (World Bank Group 2016). The combined impact of these two trends is that the global growth in demand for food and agricultural products is declining. However, even though the overall growth rate is declining, total global food demand is rising, and the OECD-FAO Agricultural Outlook 2018/27 projects an increase of around 14% in total demand for cereals, oilseeds and sugar until 2027. This demand corresponds to an extra 480 million tons of these products (OECD-FAO 2018; OECD 2018). Consequently, any improvement in production and productivity in agribusiness should be leveraged by producers, governments and other stakeholders in the industry as a mean to cope with this higher demand.

Agribusiness SC 4.0 trends and new technologies show great potential to re-shape this industry and will play a key role in the coming years. The following four macro trends emerge from a mix of technologies including biotech, IoT and big data analytics, as well as new consumer and behavioral trends like fair and responsible logistics.

Macro trend	Description	Potential impacts
Identity preserved supply chains	Genetically modified seeds create specific needs for agricultural supply chains to ensure produce is not mixed in any stage and no contamination occurs; as the development of genetically modified seeds advance into other spaces such as nutritional and pharmaceutical (creating *"agriceuticals"*), the need to guarantee and certify preserved identity becomes even more important	Even though modified seeds can increase productivity, there might be additional administrative costs to proper management. These additional costs can be reduced by using information technology tools.
New productive lands available	New genetically modified seeds, new animal adaptations and technologies such as irrigation and new fertilizers allow production in areas with worse soil conditions or more arid climates, making lands in previously unexploited areas available for agriculture and livestock production	The development of new production frontiers will require new transportation infrastructure to export commodities (roads, ports, railways). Example: New areas producing soybeans in the North region in Brazil.
Fresh & Responsible Chains	Consumers favor local food production both for green impact and social responsibility –new technology enables the construction of Vertical Farms, production sites that can be placed in big urban centers with significant impact to produce freshness and a reduction carbon footprint of the logistics process	Shorter supply chains from producer to consumer enable fresher produce availability with lower carbon footprint and lower transportation costs and spoilage reduction.
Precision agriculture	Field sensors can detect the need for specific nutrients, water or pesticides, and automated machinery and drones can leverage that data to provide what is needed automatically and to specific areas instead of applying a generic treatment to whole fields; alternatively, aerial crop survey leverages drones and satellite images together with big data analytics to determine the proper treatment for the crops	Precision agriculture can increase productivity, and reduce inputs.

In developed markets, investment in agritech startups and in R&D by large corporations such as Monsanto and DuPont give these macro trends the necessary support for their realization. The US agribusiness industry – the top global exporter of soybeans (44%), corn (34%), wheat (14%), sorghum (77%), and other nuts (46%) (Simoes 2018) – is the natural target for many of these startups. Nevertheless, these technologies and innovations can be applied at global scale, and particularly in Latin America.

Genetically modified seeds have had a significant impact in agricultural supply chains, both in terms of productivity and consumer response. Due to fear – and probably lack of knowledge or low trust levels – some consumers value products manufactured with non-genetically modified organisms (Goldberg, Ray A, Enriquez 2000). Consequently, in commodity food markets, "all-natural"

soybeans sell at a higher price point – and thus **identity preserved supply chains** are necessary to certify origin and identity of soybeans. Another example of a similar need comes from the wheat supply chain. Kennet et al. researched Canadian and US milling wheat chains to understand how the different wheat quality requirements and current grading systems impact supply chains. A case study of Warburtons Ltd, the UK's largest independent bakery, showed that the company managed to obtain wheat with varied intrinsic qualities from Canada using identity preserved supply contracts (Kennett et al. 1998, 2008). This is only the beginning: in the future, advances in biotechnology will allow the production of "tailor made" seeds for specific uses (e.g., a certain variety developed for certain type of food or recipe, to cure a certain disease, for people with certain allergies, etc.). In other words, both the existence of a certain percentage of the population that resists biotechnology (and are willing to pay a premium for non-genetically modified foods), and the natural evolution of biotechnology itself point towards an increasing segmentation or de-commoditization of the industry. This increased segmentation will require supply chains that can store, transport and process these niche products from farms all the way to consumers (hence, the need for identity preservation). Of course, under current technological circumstances, such customization violates the principles of economies of scale by potentially increasing costs significantly. The challenge for SC 4.0 is to develop new, flexible technologies that enable this "mass customization" trend at acceptable (or minimal) additional costs.

In addition to the future de-commoditization of agriculture, the role of genetically modified seeds to improve yields on exploited lands and to **make previously unexploited land viable for agriculture** is of enormous importance. For example, consider Cresud, the largest Argentinean agribusiness company and a global leader in general agriculture. Cresud has succeeded in two primarily ways: (i) acquiring, transforming and selling farmland; y (ii) operating farms on owned or third-party leased land. By maintaining a close relationship with seed developers and international agrochemical companies, Cresud was well-positioned to adopt the benefits of biotechnology in its crops, cooperating with their development. Cresud's success is not attributable to biotech alone: as the company was also an early adopter of other practices and techniques to make previously unexploited land viable for agriculture. These practices include innovations in irrigation, no-till seeding[3], modern machinery, silo bags, fertilizers and crop rotation. Additionally, the company used satellite data to evaluate the potential of plots of farmland. Taken together, these practices resulted in Cresud's yields outperforming its competitors' and allowed the company to significantly expand its operations to previously unproductive lands which it can sell at a profit after its been converted to productive farmland.

[3] No-till or zero-till is a system for growing crops without turning or plowing the earth, where equipment plants seeds directly over the residues of previous crops

Shortening the distances between producers and consumers in **Fresh & Responsible Chains** would have positive impacts both to the environment – due to reductions in carbon emissions – and to consumers – who would get fresher produce. The trend is still under development though, as alternatives to the current high-volume farm model are designed, tested and improved. These alternatives include vertical farms, the production of food using indoor farming techniques in big urban centers. Vertical farming takes advantage of hydroponics and aeroponics into new scale farms. The two major challenges of vertical farming are energy consumption and economic feasibility. Where electrical energy is obtained from fossil fuels, the benefits in logistics reduction might be neutralized by energy generation. Furthermore, the cost to build a vertical farm including the expensive land in big urban centers might be prohibitive. As technology evolves, vertical farms can become more and more energy efficient, and scale would significantly reduce building costs. Potential benefits are very promising. For example, vertical farms will not need pesticides and herbicides and water use includes recycling systems that allow for 98% less water per item of produce when compared to traditional farming. Finally, vertical farms can produce year-round due to controlled climate conditions (Marks 2014).

In **precision agriculture,** each square meter of each farm can be fertilized, planted and watered according to specific needs. For example, statistical analysis of productivity and soil composition on each area of a farm can determine optimal seed density, specific fertilizers and even seed varieties to maximize output. Another example is aerial crop survey, which shows great potential for identifying sections of crops that need treatment. The technology is originally based on the amount of near infrared light reflected by leaves compared to reflected visible light: properly hydrated leaves reflect significantly more near infrared light than dry leaves, but the visible light spectrum is reflected approximately the same. Images can be obtained by drones or from satellites and advanced software is responsible for performing image processing to determine specific areas in the crop that require further treatment and irrigation. New technology can apply big data analytics to check for patterns in images and identify other conditions. Farmers can either acquire the needed technology (drones and software) or buy it as a service from contractors – the list of available service providers and equipment manufacturers has grown significantly in the past decade, making them available worldwide. The development of cheap field and soil sensors will improve the potential of big-data-powered condition detection based on other attributes such as soil pH and nutrient levels. Consequently, crop yields are expected to increase due to improved, more precise treatments.

Other less well-known micro trends[4] also show potential for positive impact and complement the aforementioned macro trends. Some of these micro trends emerge from the application of existing technology and concepts – such as shared economy, crowdfunding and marketplace platforms – to agribusiness specific problems. Others are innovative technology solutions that do not depend on any of the SC 4.0 technologies mentioned above.

Micro trend	Description/Potential impacts
Disintermediation	Platforms that enable retailers, merchants and even consumers to source directly from producers with potential to reduce consumer prices and increase produce freshness
Collective Sourcing and e-commerce	e-commerce platforms provide farmers with access to lower prices for seeds, nutrients and pesticides, reducing costs and releasing capital for other investments
Equipment sharing	Small farmers and producers often cannot afford expensive equipment and machinery that might generate significant gains in their productivity and yields, but new shared economy solutions make it possible through equipment rents in a pay-per-use model
Spoilage reduction	Use of technology to reduce spoilage through different methods to reduce water loss
More insurance and financing	Platforms and technology allow companies to offer insurance and financing alternatives to producers due to better risk estimation or crowd funding

Implementations of these micro trends are growing worldwide. In India, Crofarm and ITC eChoupal are great examples of how **disintermediation** reduced price arbitration from intermediaries and improved small farmers outcomes due to information sharing. In LatAm, companies such as Grou in Colombia and Mas Cerca es Mas Justo in Argentina give consumers the choice to buy directly from local producers. Distinct from the Indian cases, the examples already apparent in LatAm are more focused on benefits to the customer: little or no information is available about benefits to the producer from these microtrends. In Argentina, Agrofy and Agroads are two examples of **collective sourcing and e-commerce** platforms, while BigHaat has implemented the same concept in India. Cresud was one of the founding investors for Agrofy. In terms of **equipment sharing** platforms for agribusiness, there are current examples in the US (MachineryLink), in India (Ravgo), and in Uruguay (TuCampo).

[4] See Appendix for more detailed examples of implementations of these micro trends

Silo bags, which had a major impact on soybean supply chains in LatAm, are one great example of **spoilage reduction** innovations. Other companies are working on the development of alternative measures for spoilage reduction for smaller farmers and different crops. One such example is the Belgian company Wakati which created a solar-powered humidifying device for usage inside tents. This humidifying device can keep up to 200 kg of produce fresh for up to 5 days using only 1 litter of water. Other innovative solutions came from Apeel Sciences, a startup in the US that created an extra peel technology that can be applied to fruits and vegetables to slow water loss, and from the Ugandan company Thermogenn, that developed a milk cooler for rural smallholder dairy farmers that can keep milk cool for 12 hours without electricity.

Another area where innovation is disrupting the market is **insurance and financing**. In the US, Crop Pro Insurance is offering insurance for technology and innovation adoption risks by leveraging producers' data to estimate benefits. Pula, a Switzerland based company with operations in eight countries in Africa and Asia, uses technology to offer insurance to previously uninsured, unbanked smallholders. In Nigeria, Farmcrowdy offers financing alternatives to small farmers through their crowd-funding platform, where investors can buy farm shares as small as US$250.

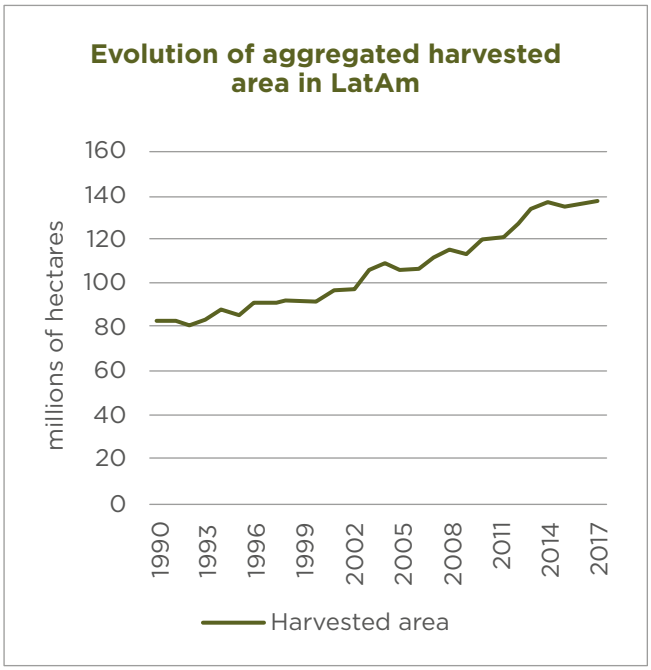
If applied together, some of these trends can have major impacts on industry outlook. For example, Argentinean agro-industrial firm Los Grobo, leveraged genetically modified seeds together with a network business model that promote economies of scale in the soybean market. The company leases most of the land for production from landowners and pays them a fixed or variable fee. Independent affiliated Agronomists are responsible for growing crops on these lands and are paid a share of the crop yield. Designated contractors offer services such as sowing, fertilizer application, herbicide spraying, harvesting and logistics – whose prices are centrally defined by Los Grobo. The company leverages central purchasing of seeds, fertilizers and herbicides that are later sold to Agronomists through local Los Grobo branches. The whole network benefits from Los Grobo's technology platform that requires and fosters intensive information sharing regarding techniques, problem solving and best practices.

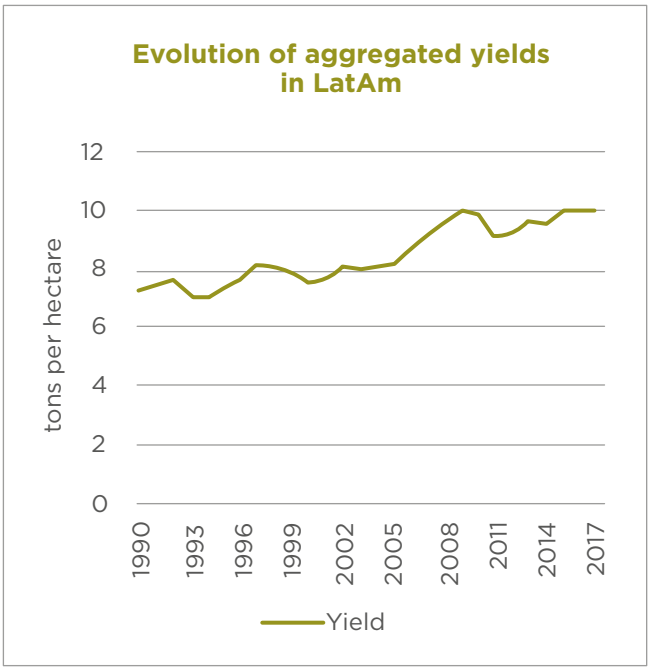
4.3 Preliminary Impact Estimation

Since SC 4.0 has not yet unfolded, at least not as a consolidated emergent phenomena, it is extremely difficult to provide a precise impact estimation. However, a rough, order of magnitude estimation can serve as a guide for prioritization in resource allocation, policy focus, education, etc.

Due to the complexity of a wholistic impact estimation, this paper focused on an impact estimate limited to the agribusiness sector in LatAm, a sector already vital to the LatAm economy and likely to be impacted by S.C. 4.0. In this framework, the expected output is dependent on two main variables: total harvested area and yield. Historical data on these two variables is publicly available in the OECD-FAO stats library (OECD 2018) for the available products[5] from the region, and are extrapolated from there based on the estimated impact each trend can have on each variable: land exploitation and yield improvement.

In the charts below, both yields and harvested area experienced significant growth after 2005, with yields quickly rising to 10 tons





per hectare in 2009 and reaching a plateau. At the same time, the total harvested increased almost linearly up to 2013, when growth significantly declined to around 138 million hectares. The overall trend since 1990 shows a clear growth pattern, with a softer pattern for harvested area and more fluctuation for yields.

This framework shows annual production can increase by up to 24% in the next decade, in contrast with the 13.2% forecasted by OECD-FAO Agricultural Outlook 2018-2027 (OECD-FAO 2018), as SC 4.0 is embraced by agribusiness stakeholders. Total harvested area has grown 1.6% per year in the period between 2002 to 2017, and only 0.6% per year from 2013 to 2017.

[5] Data available include soybean, other oilseeds, wheat, maize, other coarse grains, rice, sugar cane, sugar beet, cotton, and roots & tubers.

This growth can increase to 1.5% per year as new technologies including genetically modified seeds, irrigation, seeding, machinery, storage, fertilizers and techniques make previously unexploited lands available for agriculture. In other words, new technology will be able to permit a continuation in planted area growth at the average rate of the last 15 years. Yields have also grown around 1.4% per year between 2002-2017, and only 0.7% during the 2013-2017 period. Increasing yield presents different challenges than increasing the total planted area. In highly productive areas, despite the fact new technologies can improve yields, there will be decreasing returns. At the same time, newly planted areas will, on average, be less productive than existing areas. Taking this difference into account, yields have the potential to keep growing at the rate of 0.7% per year, i.e., at the rate of the last five years rather than at the average rate of the last 15 years. Combining the effects of yields and expanding areas, overall output growth reaches 24%.

This increase in output will only be feasible if the corresponding infrastructure is able to cope with it. In other words, increased farm output can only get to market if roads, railroads and ports allow this extra production to be transported. Future infrastructure demand forecasts must consider the evolution of this particular sector, and include these technological developments in their outlook.

On the labor front, world employment in agribusiness has been decreasing steadily. For example, on a global scale, agriculture represented approximately 45% of the labor force in the early 90´s, but only 27% in 2017 (The World Bank 2018). In developed countries, agriculture represents a very small (and declining) percentage of total labor. For example, in the US the percentage declined from 2.73 to 1.66 in the same timeframe. In Spain, this metric fell from 10 percent to 4 percent, while in Australia and France it declined from 6 to 3 percent (The World Bank 2018). This is not just a relative decline, but also a steep decline in absolute numbers. For example, total US farm employment including farm owners, their families and hired labor, fell from approximately 10 MM people in the 50s to a little over three million over the last decade (USDA 2018). LatAm has been no exception to this trend. For example, in Mexico total farm employment dropped from 27 percent of total labor in the 90s to 13 percent in 2017. At the same time, Brazil´s agriculture employment share fell from 28 percent to 10 percent. The impact of industry 4.0 on agribusiness in LatAm will likely accelerate this trend, moving LatAm´s employment figures closer to the current numbers in developed economies. This could mean a decline from the current 30-40 percent range prevalent to a 5-10 percent range, or even lower depending on the sub-sector (e.g. soy may require less labor than coffee). Clearly, in this industry loss of jobs will be a significant challenge, even if this loss is offset by growth in other areas. Increased total production will be the largest economic impact of SC 4.0 on agribusiness, but the job loss will create social challenges that may or may not be mitigated by macro-economic gains. In addition to this issue, there are going to be impacts of SC

4.0 in other areas such as total production costs (including logistics costs), employment and greenhouse emissions. Even though it is difficult to make predictions at such an early stage, future research should attempt to provide order of magnitude estimates of these effects.

4.4 Policy discussions

To help these technological trends achieve their potential, governments, international financial organizations and universities can play a significant role in fostering their adoption and helping to establish a smoother transition path.

Both increased yields and larger (and potentially more distant) planted areas will eventually lead to an increase in demand for transportation infrastructure – not only to expand existing infrastructure, but also to build new infrastructure in areas where agriculture might not have been feasible before. Governments need to be vigilant regarding the state of current infrastructure, on the evolution of yields and planted areas, and on the advances in these technologies and their potential applications to specific regions. This knowledge will allow for proper investment by the state. International financial organizations should find great opportunities for positive regional impact projects among these transportation infrastructure projects, as well as by funding research projects related to biotech and the top exporting agribusiness products in LatAm. Universities can contribute not only through innovative research and education, but also by joining the effort to monitor each technology and trends adoption and evolution.

Collective sourcing and e-commerce can drastically alter the supply chain topologies, as the continuous reduction in transaction costs enabled by technology allow small companies to join the supply chain either upstream (small producers) or downstream (e-commerce distributors). Nevertheless, some barriers imposed by governments, particularly those related to customs (in international transactions), value added taxes, for domestic trade, or other regulations designed for large stakeholders, can prevent small companies from joining the supply chain.

Governments should anticipate these trends and design policies that will enable small companies to avoid such barriers, for instance streamlining customs procedures.

Fresh chains and vertical farms may shift the current balance and impact global agribusiness supply chains by moving production closer to big urban centers. Such trends could lead to a reduction in global demand for produce exporting countries and reduce long haul transportation demand both in exporting and importing countries. Vertical farms would initially impact big urban centers, and some of the biggest cities in the world are in LatAm, which is

approximately 80% urban (United Nations 2018). Governments will need to regulate this practice in terms of food safety, zoning for vertical farms and other specific requirements.

Also, in the context of vertical farming, exporting countries in LatAm may face a reduction in demand from importing countries. To compensate for this loss, governments in the region should expand their trade agreements outside the region to create new opportunities for exports.

In all scenarios, governments and international financial institutions should increase the amount of credit offered to companies in biotech and agritech to promote innovations that can make currently unexplored lands productive, and to farmers and producers, to adopt new technologies to improve productivity.

Finally, investment in education is a high priority, not only in biotech but also in technology, robotics and IT. Adopting these SC 4.0 trends and innovations will require specialized knowledge in the hands of both farmers and producers in LatAm. Universities, governments and international financial organizations will play a central role in proposing, launching and financing these education programs.

Photo by Gozha Net

CHAPTER 5

Conclusion and future directions

This paper summarized the current global state of Industry 4.0 and Supply Chain 4.0 literature, and presented a framework/approach to adapt to the realities of LatAm, using an initial assessment of Agribusiness as an example. Although this paper is a step in the right direction, it is only one step of an ongoing process. It is crucial to undertake constant monitoring of the state of Supply Chain 4.0 in LatAm, to anticipate and react to trends/innovations/changes as they happen, to refine impact estimates to guide the establishment of priorities, and guide policy makers across the region as the situation unfolds. The region has enormous potential and has already demonstrated that it can stand at the forefront of technological change. For example, LatAm has created nine "unicorns" (i.e., startup companies worth more than US$1 billion), which are collectively worth US$23 billion (iProfesonal 2018). However, this revolution has been concentrated within the information sector SC 4.0 so far. As mentioned above, the region is already a world leader in agribusiness and the use of biotechnology applied to this industry. However, the maturity of Supply Chain 4.0 physical practices is low. Also, this analysis indicates that the penetration of Supply Chain 4.0 practices to other industries is mixed: something highlighted in (Inter American Development Bank 2018a). In that report, the IDB authors propose that this is the case because while purely digital technologies can be applied globally without a lot of adaptation, the same cannot be said of technological developments

that apply to production processes. This conclusion is supported by the research presented in this paper. In other words, left to their own devices, the region´s entrepreneurs have focused on only one aspect of future development. This is why a thorough, attentive and ongoing monitoring plan is required. At the same time, decisive, sustained policies that adapt to the changing realities can help catalyze the adoption of state-of-the-art practices across all key industries and regions.

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APPENDIX I

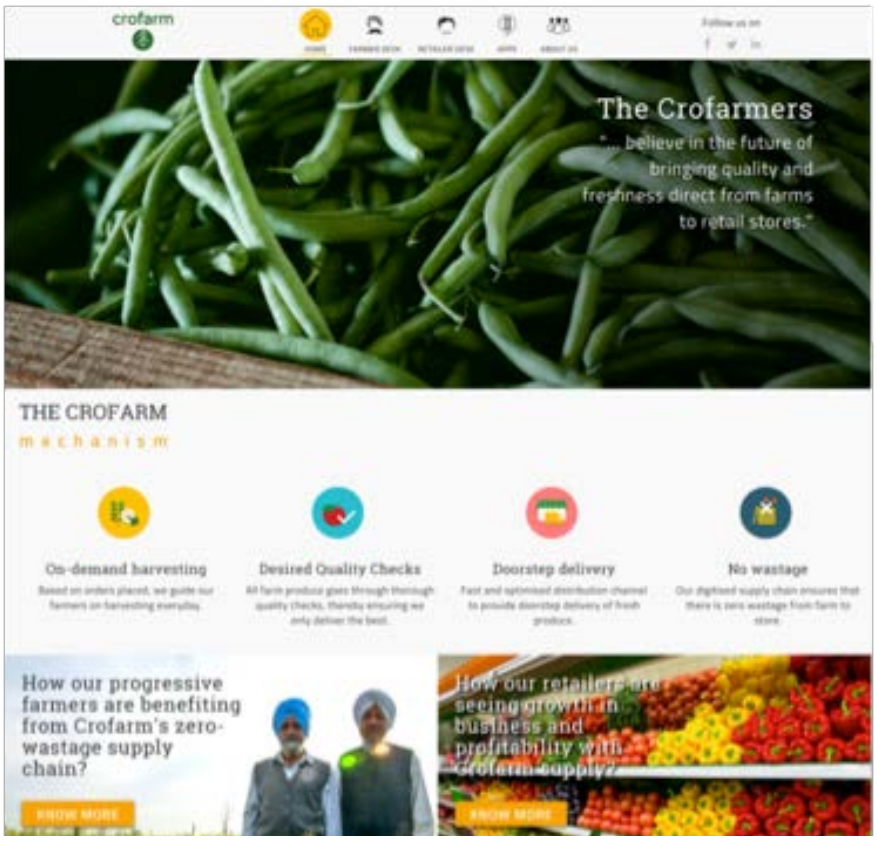
Photo by Yulian Alexeyev

Micro trend initiatives, startups and companies

A _ Disintermediation

In India, disintermediation has been fostered by platforms that enable sourcing directly from producers. In many regions, these producers used to have very little negotiation power in the traditional channel: the mandi, the physical marketplace. Two examples of companies utilizing direct sourcing are Crofarm and ITC eChoupal.

Crofarm connects retailers and producers through a digital platform where producers get transparent information on what sells in the Indian market and at what price. This allows them to improve quality and make better pricing decisions, as well as to adopt on-demand harvesting: the platform will guide them on harvesting everyday based on orders, resulting in fresher produce and better prices. Retailers can place their orders on the app roughly 8 hours before and receive the fresh produce conveniently at the store. Digital payments are encouraged reducing the need to handle cash at retailers. With the platform, the end-to-end supply chain is more responsive, and both retailers and producers get better deals in terms of price and quality.



ITC eChoupal offers producers an alternative to the traditional marketplace, the mandi. Before the initiative, rural farmers and producers in some regions of India used to sell their produce just like their ancestors did for decades in the local mandi. After harvesting, farmers took their produce to the mandi where practices put them at a disadvantage. ITC depended on the mandis to buy produce and knew that agents could benefit from arbitration, and as a counter measure it decided to launch the eChoupal platform (choupal means gathering place). With the IT platform, producers gathered at the village to learn about current market prices, production and demand, as well as growing techniques and the weather forecast. This knowledge led to more informed decisions concerning when to harvest and where to sell their produce.

B _ Collective Sourcing and e-commerce

Collective sourcing and e-commerce platforms enable transaction cost reduction and gains of scale due to higher volumes. In LatAm, we identified some examples such as **Agrofy** in Argentina.

Agrofy offers farmers and producers a central e-commerce platform to source the entire range of supplies and equipment they need to raise their crops. It partners with suppliers to offer their products in the platform, and producers later buy them from Agrofy, concentrating the purchasing and logistics and leading to gains of scale. The platform simplifies the procurement process for producers and offers the possibility of lower prices. Cresud, the leading agribusiness company in Argentina, is one of Agrofy's founding investors.

C _ Equipment sharing

Equipment sharing allows small farmers who cannot afford to invest in equipment to improve their yields and productivity through rental. In Uruguay, **TuCampo** offers a platform for equipment rental and field services hiring. Equipment owners and service providers register on the platform to offer their services, listing which areas they can cover, and producers use the platform to rent or hire from an equipment owner available for the time span they want the service to be executed. TuCampo acts as an agent, connecting supply and demand and leading to better prices and higher asset utilization.

D _ Spoilage reduction

Spoilage reduction innovations can increase net yield and improve producers' profits. Some innovations, such as silo bags, had a significant impact for large farmers for soybeans in LatAm. Other innovations that might affect smaller farmers were introduced by Belgian company **Wakati**. Wakati is a solar-powered standalone solution to protect crops from spoilage. Its technology enables the storage of up to 200kg of vegetables and fruits using 1 litter of water per week. The humidified microclimate inside the product tent leads to increased freshness, particularly for short periods up to 5 days before produce delivery. The company first applied its product in areas of Uganda where cooling availability was an issue for producers. The increase in produce freshness allowed producers to charge better prices, increasing their profits, but other effects can also be perceived downstream in the supply chain benefitting customers.

E _ More insurance and financing

Big data enabled risk evaluation and crop monitoring enable companies to offer different insurances to producers. One example is **Crop Pro Insurance**, from the US. The company offers producers insurance for technology and innovation adoption risks, increasing their incentives to try leading agriculture technology. For instance, a producer might be reluctant to try non-GMO (Genetically Modified Organism) seeds even though new biological crop protection products exist. The company works with producers' data to estimate the benefits and provides insurance for those benefits. Next steps might include offering both technology and insurance together.

An alternative to standard funding is crowd funding. In Nigeria, small producers can finance their farms with **Farmcrowdy.** The company works with potential farmers through a selection and due diligence process before launching them as an offer. Investors pick the farms they want to sponsor directly in the platform and get bi-weekly updates on how their farms are performing as well as the estimated time for harvesting and profit collection. Risk spreading is the basis of the business: investors can buy farm shares as small as U$S250. The effort finances new business that would not be possible otherwise.