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Digitalization and Platforms in Agriculture: Organizations, Power Asymmetry, and Collective Action Solutions

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Digitization and Platforms in Agriculture: Organizations, Power Asymmetry, and Collective Action Solutions*

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ABSTRACT

Technologies such as digitally-equipped agricultural equipment, drones, image recognition, sensors, robots and artificial intelligence are being rapidly adopted throughout the agri-food system. As a result, actors in the system are generating and using ever more data. While this is already contributing to greater productivity, efficiency, and resilience, for the most part, this data has been siloed at its production sites whether on the farm or at the other nodes in the system. Sharing this data can be used to create value at other nodes in the system by increasing transparency, traceability, and productivity. Ever greater connectivity allows the sharing of this data with actors, at the same node in the value chain, e.g., farmer-to-farmer, or between different nodes in the value chain, e.g., farmer-to-equipment producer.

The benefits of data sharing for efficiency, productivity and sustainability are predicated upon the adoption of an online digital platform. The conundrum is that, as the intermediary, the owner of a successful platform acquires significant power in relationship to the platform sides. This paper identifies five types of platform business models/ownership arrangements and their benefits and drawbacks for the various actors in the agri-food system and, in particular farmers. The types discussed are: 1) venture capital-financed startups; 2) existing agro-food industry firms including equipment makers such as John Deere, agrochemical/seed conglomerates such as Bayer/Monsanto, and agricultural commodity traders such as ADM and Cargill; 3) agricultural cooperative such as InVivo in France; 4) various specially formed consortia of diverse sets of agri-food system actors including farmers, and 5) the internet giants such as Amazon, Microsoft and Google. The paper assesses the business models for each of these organizational forms. Finally, we describe the drawbacks each of these organizational forms have experienced as they attempt to secure adoption of their particular platform solution.

Keywords: Digitization, Platform Economy, Agriculture, Agri-food systems, Cooperatives, Platforms.

1. Introduction

In 2016 *Wired* proclaimed: "the future of agriculture is in the hands of the [digital] machines (Simon 2016)." More precisely, there is a struggle underway as to how the agri-food system will be structured in what Kenney and Zysman (2016) termed the "platform economy." Platforms and intelligent tools including big data, drones, image recognition, sensors, robots, and artificial intelligence that are organizing economy (Zysman & Kenney, 2018) are disrupting agriculture and food industries and providing opportunities to develop new business models or reconfigure older ones (on business models, see Zott and Amit, 2017).

Incumbent agribusiness corporations, fertilizer vendors and equipment manufacturers to food processors, venture capital-funded startups, and agricultural cooperatives are among the variety of organizations introducing business models to exploit an agriculture being transformed by digitization and platforms. Even as for-profit firms attempt to use digital technologies to transform agriculture, other organizations such as cooperatives and non-profit organizations are being formed with the express purpose of ensuring that the introduction of online platforms does not force farmers to become what Cutolo and Kenney (2020) term "platform-dependent entrepreneurs." All of these organizations promise more efficient and sustainable solutions to economic, environmental, ethical and social difficulties, agri-food systems are challenged with to ensure global food security (Busse et al., 2015; Carolan, 2017; Wolfert et al., 2017; FAO, 2019).

The impacts of computerization and platforms on business and labor processes in the agri-food system has drawn increased attention (Wolfert et al., 2017; Bacco et al., 2019). Remarkably, less attention is paid to the difficulties faced by organizations seeking to establish digital online platforms in the agri-food system as they try to persuade farmers and other actors to participate in them by sharing and providing access to their data, a necessity for the platform viability. For the actors expected to provide the data, the question of how they will share in the value generated from the data is unanswered.

The impacts of digitization, like other powerful general-purpose technology, will be varied and complex. The current technological regime in agriculture depends upon the use of the internal combustion engine, the application of petrochemicals, and breeding plants optimized for response to chemicals that dramatically increase yield (e.g., McMichael, 2009). Petrochemical-based agriculture affects all corners of the agri-food system—production, processing, distribution, and retail. Its adoption supported rapid suburbanization and a technological treadmill for farmers, resulting in an enormous carbon footprint and concentration in fewer but larger firms. This system creates challenged not only for smaller farms but also for independent food processors, which has increased their concentration. Food supply chains lengthened dramatically, became more complex, and led to the production, distribution, and consumption of "placeless" factory-processed, packaged, and easy-to-prepare food products. Consequently, in these food chains, traceability decreased significantly. As a result, disruptions or adulteration became difficult to address.

The increasing contradictions and criticisms of the current regime encouraged technologists, business leaders, politicians, and the popular press to suggest that the rapidly advancing digital technologies—with their use of sensors and data- and computation-intensive precision—could address many of these vexing problems. One promise of digital technologies and the platforms that aggregate and analyze the data is that they can facilitate the deployment of equipment and expertise to sustainably produce and distribute agri-food products. Data-intensive agriculture might contribute to the achievement of the UN Sustainable Development Goals (United Nations DESA, 2017) by making agri-food systems more productive, efficient, socially inclusive, transparent, traceable, and resilient (FAO, 2017). It promises an increase in quantity, product quality, and safety, while reducing costs, waste, production losses, and agrichemical use (FAO, 2019). Thus digital technologies can facilitate alternative paths for agriculture.

This paper aims to provide an overview of the new horizons opened by the globalized agri-food system to design new business models bases on data creation and analysis. As agri-food system are intimately related to agricultural resources and farming practices (Trystram & Serhan, 2020), this overview is more focused on farmers, and thus relegates many of the other actors in the agri-food system, such as, food processors, distributors, final consumers to the background. In the interest of space, our overview must overlook the distinctions between row and tree crops, meat and renewable animal production, open field and greenhouse production, and rural and urban agriculture. Each of these will have different patterns of resource use and social, economic, and environmental impacts.

2. Agriculture and Digitization

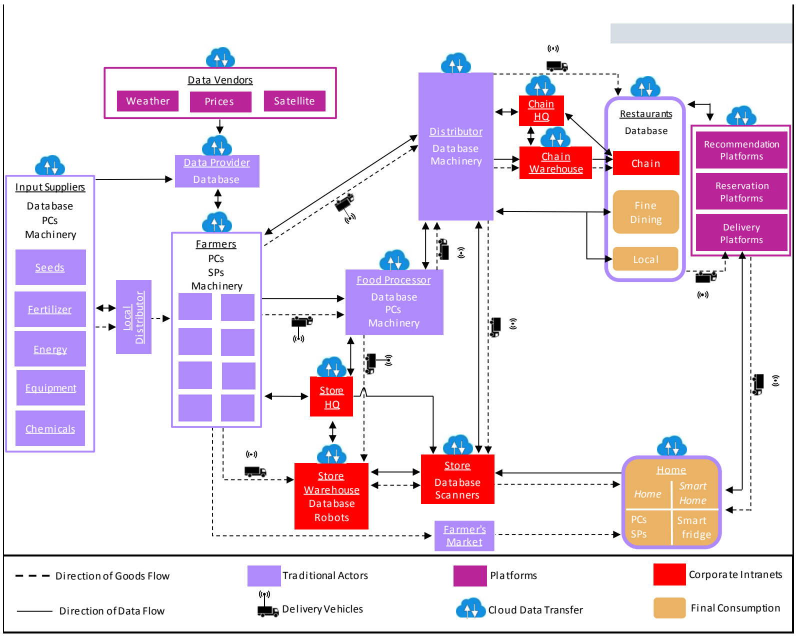
The impact of digitization on agriculture can be observed at three levels: micro, meso, and macro level. At the micro level, change has taken place even down to single machines. Whether they are drones, tractors, milking machines, packaging machines in a food-processing plant, a cow with an implanted chip, or an autonomous vehicle—they all produce data that can be analyzed to optimize performance. At the meso level, the data produced by these machines can be integrated into complexes of machines and people on the farm, in the factory, and at an entire organization. The data can be integrated into cross-organizational systems, such as multi-firm supply chains and beyond. Finally, at the macro level, many questions arise—and among them, one of the most important is how all this data will be organized, who will own it, and, in particular, will digital platforms be constructed and who will capture their benefits. At each level, questions exist as to who owns the data and how access and the ability to analyze data transform power relationships, worker and farmer skill requirements, and other matters.

Agriculture is a quintessential space-based industry exposed to the vagaries of nature. Particularly when it takes place outdoors, agriculture faces unique kinds of uncertainty from natural events, such as extreme weather and pests, as well as plant diseases and insects can invade a field. Moreover, this uncertainty pertains to the fact that all fields and all parts of a field are unique and may experience location-specific problems. Market vagaries are also endemic, because good harvests—i.e., excellent efficiency in converting inputs into outputs—can lead to lower earnings if other farmers experience similarly good fortune. Moreover, crop farmers invest in the entire growing season prior to harvest. These uncertainties mean that farms have a production function different from that of most firms and are often risk averse and reluctant to adopt unproven technologies.

The agri-food value chain is simple and yet quite complex, with different market conditions at each node in the chain. Agri-food systems are composed of a great variety of products, each with its own value chain. Figure 1 is a stylized depiction of a generic value chain that extends from input suppliers to final consumers and assumes that all actors have digital connectivity. Each node might have multiple software systems that do not intercommunicate, despite the development of international interface standards for interconnecting agricultural implements (e.g., ISO 11783).

In the current food regime, a farmer purchases inputs, many of which are produced by highly oligopolized food producers and purchased from local distributors. A relatively new and burgeoning group of input suppliers are data vendors that provide weather, remote sensing, price, and other types of data. Farm output is sold predominantly to the food processors or to retailers—alternative sales pathways, such as farmers' markets, are still relatively small. Although farming is becoming more concentrated, there are far more farmers than suppliers, processors, or retailers. Restaurants are the only similarly dispersed node in the value chain, and they are increasingly intermediated by platforms such as Yelp. Finally, platforms such as Amazon are trying to intermediate final sales to consumers. Because of their vulnerable position, farmers and consumers have frequently organized producer cooperatives to improve their bargaining power.

Figure 1: Stylized Food System in the Digital Era



The improving functionality of sensors and software enable the increasing automation of agricultural equipment; the introduction of in-field and remote sensors for moisture, nitrogen, soil, and air temperature; capturing animal vital signs in real time; monitoring myriad other environmental variables; and GPS. These and other digital technologies, combined, make possible what is called "precision agriculture," which is expected to address problems in conventional agriculture. For example, sensors, both in the field and remote, and the increased capability of farm equipment to variably apply fertilizers, pesticides, and seeds, are improving the efficiency and efficacy of inputs and thus limiting their impact on the environment (Revich et al. 2016). Grain harvesters can measure the yield, protein, moisture content, and even the amount of impurities in real time and in an exact location in the field. With this shift to software for collection, measurement, and decision making—and given the fluidity of data—power could shift to the organizations that are capable of extracting value from the data.

In the next section, we explore how this is creating commercial opportunities for the introduction of digital platforms to address problems in contemporary agriculture.

2. 3. Digital Technologies in Agri-Food Systems

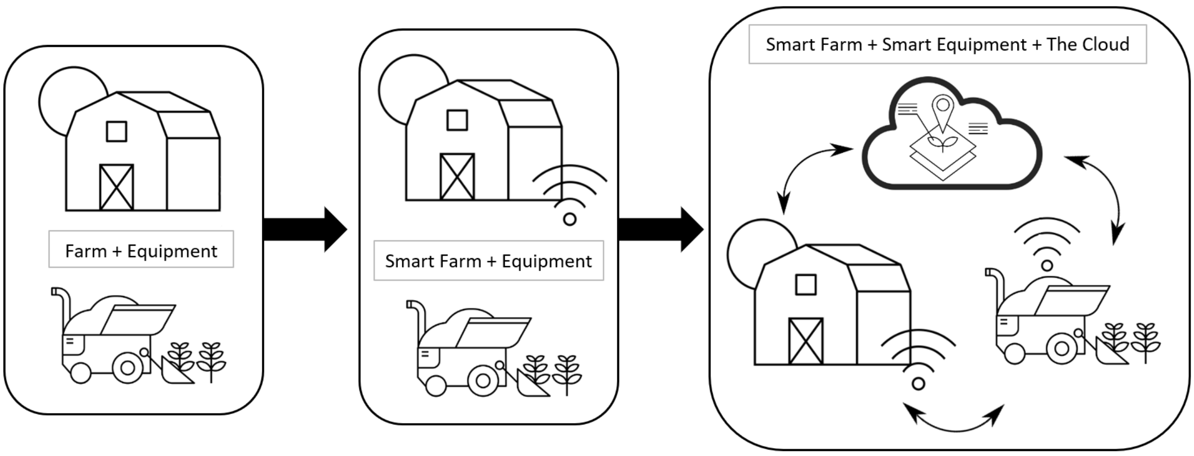
Large firms quickly adopted computerization to manage external functions, such as human resources, finance, operations management, and logistics. At the time, these functions did not communicate with one another; rather, they were computerized islands. As computerization advanced, these systems were interconnected. In many sectors, powerful buyers introduced proprietary electronic data interchange systems to connect internal operations and input suppliers, thereby simplifying supply chain management. At this early phase, farmers were largely unaffected unless they were contract farmers integrated into their customer's electronic data interchange systems. Digital connectivity for data interchange in agriculture advanced steadily through proprietary systems, though, as a rural activity, it was plagued by inferior connectivity (e.g., LaRose et al., 2007).

After the arrival of the personal computer, farmers and hobbyist entrepreneurs began to develop software for farm-specific applications and adopted general programs, such as Excel for compiling spreadsheets (Goe and Kenney 1986). The decreasing cost and increasing capability of microprocessors made it possible to put a computer on a chip and couple it with a sensor. Not surprisingly, equipment was introduced with more sophisticated sensors and greater processing power. The integration of computing power into machines used on farms—

milking machines, tractors, etc.—enabled them to become “smart.” This informated equipment was increasingly connected with the personal computers of farmers (Smith et al., 2004).

Roughly contemporaneously, off-farm information began to be delivered to farmers’ computers through modems and dial-up telephone lines. Initially, subscription services largely pushed information, such as commodity prices and farm-specific news, to farmers. As they became connected, farmers also rapidly adopted email and joined chatrooms, etc. The introduction of the World Wide Web in the mid-1990s transformed information access and interactivity. Agriculture-specific websites for e-commerce, information and news, commodity trading, and various other activities were launched in the mid-1990s. As in the rest of society, farmers connected to the internet for all sorts of activities, goods, and services. As Figure 2 shows, first, farms adopted computers; then, their equipment became smart, and farms became connected to the cloud. Increasing digitization also shifted the source of the value of agricultural machinery. In 2015, 30 percent of the value of agricultural equipment came from software, electronics, and sensors (Giesler, 2018).

Figure 2



Adapted from Porter and Heppelmann, 2014.

GPS was a critical technology in the digitization of field agriculture because it could locate things, making "precision" possible. With GPS, it was possible to represent farmland as layers of digital datasets, i.e., soil types or moisture, describing characteristics of geographical space (Mateescu & Elish, 2019: 10). Similarly, although animals were already modeled as machines, they could now be digitally monitored, and the data collected facilitated further their optimization in the production of milk, meat, or hides.[1]

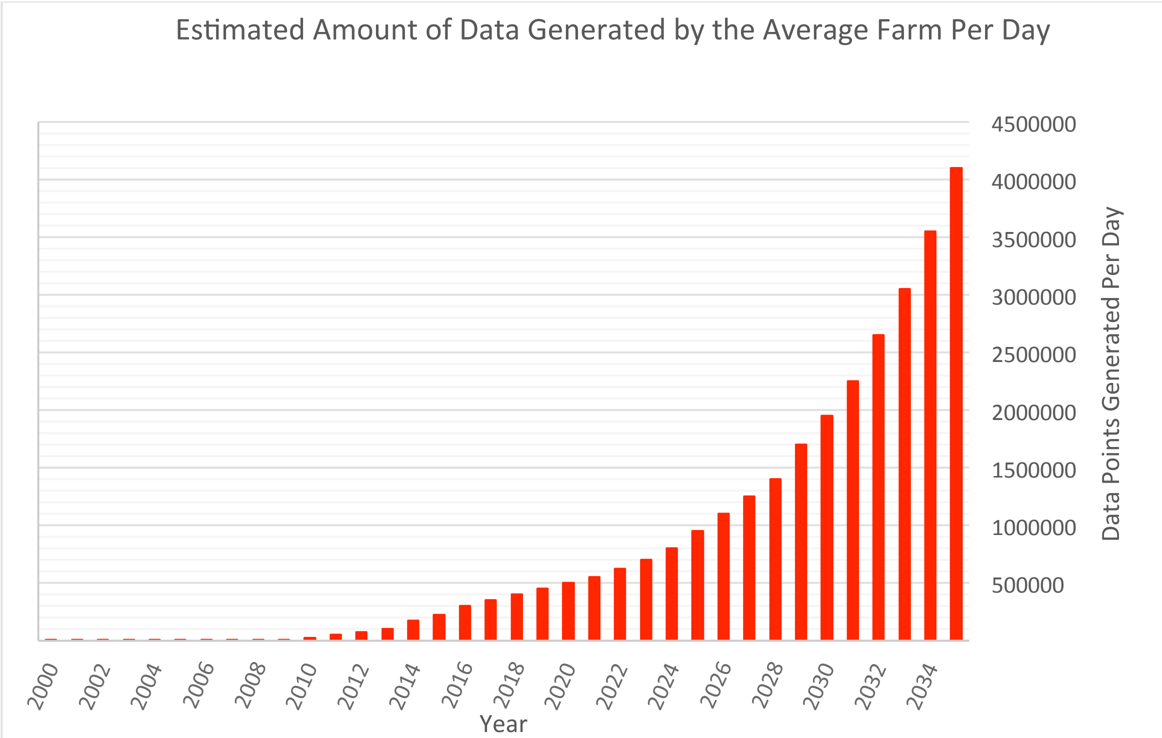
Previously, farmers decided when to plant, apply fertilizers and pesticides, water, and harvest based on accumulated knowledge and experience—it was a "craft-based" process. In the era of "dumb" machines, inputs were applied to an entire field or orchard. This began to change as farming equipment became informated and therefore capable of greater precision in the application of chemicals, water, and other inputs. Today, fertilizer sprayers are guided by application maps tailored to each part of the field—each spray nozzle is controlled independently. In the future, it will be possible to assess the condition of individual plants and identify weeds or pests and individually treat them. This precision already exists in dairy operations, in which customized feed rations are provided to each animal. Beyond cost savings, the application of the optimal amount of agricultural chemicals decreases the environmental impacts (Bongiovanni & Lowenberg-DeBoer, 2004).

Both machine and human interactions with "smart" machines generate data that, when aggregated and analyzed, can produce value. According to John Deere, "the average farm went from generating 190,000 data points per day in 2014 to a projected 4.1 million data points in 2020 fueled by the significant growth of sensors placed in fields and digitized equipment" (Snyder & Castrounis, 2018). Figure 3 illustrates the rapidity with which data

[1] Of course, these tendencies already existed in industrialized agriculture.

production is increasing. In a data-based economy, understanding how to process and extract data and determining which data is valuable to whom is critical.

Figure 3 Estimated Amount of Data Generated by the Average Connected Farm per Day



Source: Meola 2016

3.1. The Combine as an Illustration

The evolution of the combine harvester illustrated in Figure 2 is a quintessential example of how agricultural equipment has become more computerized. In particular, the combine evolved a machine towed by horses to one powered by an internal combustion engine with mechanical controls. In the 1980s, electronics were introduced to farm equipment to replace the more expensive mechanical parts. Initially, the replacements were quite simple, such as replacing analog gauges and sensors with digital ones. Also during this period, on-board engine computers were introduced to control the internal operations of the equipment to ensure it operated properly and efficiently. Later, environmental sensors, digital displays, cameras, etc., were added. GPS equipment was added, making it possible for field equipment to spray in specific locations in a field and enabling more efficient and effective plowing. Other sensors were added to measure yield, crop and soil moisture, protein content, soil nutrient levels, pests, and a variety of other valuable data—all of which could be correlated to specific locations in the field. All this data could be stored in the cloud, where it could be combined with data from other sources.

The successful evolution to full autonomy may be simpler of the combine than for the automobile, because combines operate in relative isolation. Combines have little need to interact with human beings or vehicles, and if the combine is confused, it simply halts, calls for assistance, and waits for someone to diagnose the problem. Autonomous combines have already been introduced in Japan and other countries facing agricultural labor shortages due to aging (Rich, 2018).

The combine's evolution to a cloud-connected piece of equipment is only one example of the evolution of agricultural and, indeed, all capital goods. As equipment becomes informated and connected, the data it produces become more valuable, interactive, and capable. Data generated by field equipment may be valuable to many different actors and even competitors in the value chain, including banks, food processors, crop insurers, or even commodity traders—many of whom were previously considered ancillary to the traditional agri-food value chain. As farmers and other actors are increasingly interconnected, new digital services, such as smartphone-based image recognition for pests or plant health diagnosis, are being introduced.

As digital technologies permeate and informate more agricultural activities, data are becoming increasingly granular, which enables detailed analysis. Software is already changing how farmers farm and how they are integrated into the food system, and this will continue. What becomes of the work of a farmer if robot combines harvest fields or, even more transformative, if an increasing proportion of food is grown in largely automated indoor facilities? These changes will reverberate throughout the value chain, affecting input providers, local agricultural input suppliers, processors, and suppliers to the final consumer.

3. 4. Platforms Explained

In technical terms, an online digital platform is a "site" composed of software that enables multi-sided interaction among independent parties (e.g., Ghazawneh & Henfridsson, 2013). Platforms are intermediaries between independent parties, which are often called the "sides" of the market or platform (Boudreau & Hagiu, 2009; Evans, 2003). They are not just technical systems or neutral arbiters; they are also governance structures. To be successful, a platform must attract participants. For example, to create a successful platform, John Deere must attract farmers and app designers. To entice participants, platforms provide resources and services, such as APIs, software development kits, payment systems, and access to its users, i.e., a market.

If a digital platform is designed properly, it can attract complementors to form an ecosystem of organizations that operate through and create value for the platform and its users (Gawer & Cusumano, 2014). Successful platforms grow by attracting users and service providers, thereby initiating network effects, and, ceteris paribus, as the value of the platform grows, the more value it can create and capture. These network effects often lead to winner-take-all (or most) dynamics. Moreover, those who use the platform can experience lock-in effects, which makes it difficult to change platforms (Tiwana, 2013). Finally, successful platforms often benefit from long-tail markets, as the plethora of complementors offer users a wide variety of choices (Brynjolfsson, Hu & Smith, 2010).

As an intermediary, the platform has a panoptic view of all activity on it. The key to the power of a platform is its ability to "tax" ecosystem participants for using it. Of course, this is not necessarily negative, as the platform provides those in its ecosystem with many benefits

(Cutolo & Kenney, 2020). Yet the ecosystem metaphor ignores the power of the platform owner. When the lock-in of a platform is greater, participants are less able to leave it. Successful for-profit platforms are monopolists aiming to extract as much value as possible from those transacting through it, limited only by their need to prevent the complementors from abandoning the platform. In agriculture, the adoption of a single digital platform could lead to remarkable efficiencies as well as environmental and other benefits.

Data generated or captured by one actor is often of little value to that actor but could be valuable to another. Persuading actors to contribute their data faces significant obstacles. Data sharing can reveal intimate details about the generator's operations. A common challenge is determining how actors will be compensated for the data they generate. Ownership and usage rights are even more difficult to contract for because data is not static, but rather comes in ongoing streams. Finally, data generators cannot ascertain the current or future value of their data stream.

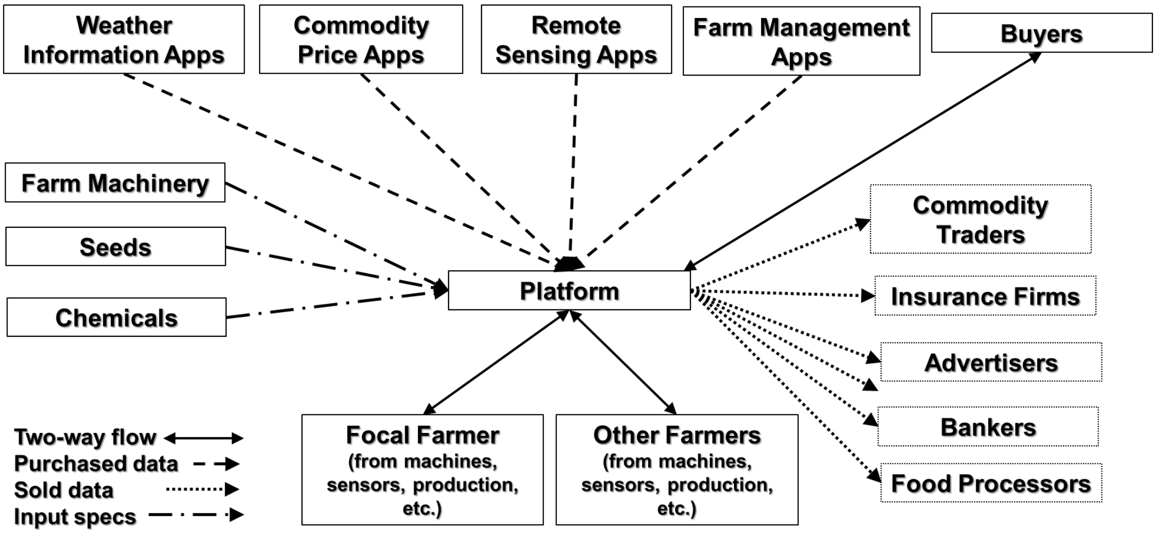
Sharing data also means providing it in a certain format, which creates a form of lock-in unless the data are standardized. Another form of lock-in may occur if the data are analyzed in the cloud, and those results are transmitted to the farmer, particularly if the results are optimized or useful only for a certain brand of machines or cloud platform. Further, depending on the contract, if the platform is sold to another firm, the data is also sold. The arrangements necessary to ensure that each party is treated fairly (if that is one of the goals) will be complex and difficult to implement.

4. Platforms in Agriculture

Farms generate enormous amounts of data. In Figure 4, we illustrate data flows that a farmer-centric platform could aggregate and analyze to provide value to various ecosystem participants. Farm machinery generates many kinds of data and, in most cases, contracts between farmers and manufacturer confer ownership of all the data created to the manufacturer. For example, a combine generates data about location, activity, field conditions, and its own operations, such as engine heat, torque, speed, and the operation of parts. A farmer might be delighted to provide operational data so that the machinery manufacturer can diagnose problems and warn the farmer before they occur in the field. However, farmers might be reluctant to share data related to their business profitability, yield, etc. as it is unnecessary for the machinery manufacturer.

For each platform, the goal is to attract as many users as possible, as they provide data that initiate same-side network effects. Increasing the proportion of all farmers on the platform will make the data more complete, and thus valuable, and will ensure that predictions are more accurate. Adding other data, such as weather, commodity prices, and remote sensing, should further increase the value of the platform. Similarly, input specifications from the chemical and seed industries could provide even greater value. For example, chemical applications could be optimized or yields could be correlated with the seeds planted. The ability to standardize and analyze this enormous pool and flow of data might lead to more efficient and sustainable farming.

Figure 4. Date Flows through an Agricultural Platform



Until recently, data was spotty and ex post. In contrast, connected devices provide up-to-the-minute data not only to farmers but other platform participants. For example, commodity traders could use such data for trading, insurance firms and banks could use the data to constantly update risk assessments, food processors could better plan production, and regulators could use data to understand pollution run-off. Thus, if irrigation devices are digitized, they could be monitored and optimized in real time. Additionally, the data could be used to target advertising to specific farmers. The centralization of the data and complementors on a single platform would make that platform the equivalent of Amazon or Google and could allow complementors to introduce greater functionality through apps.

The drawback to a centralized platform is that it would be dominant and could capture a preponderance of the value created. With a centralized platform all of the other actors in the agri-food system would be vulnerable. In the next section, we explore the different organizational forms for platform governance being introduced.

6. Platform Business Model Organizational Forms for Agriculture

Over the past decade, investors and existing businesses have recognized the potential for platforms to reorganize industries. This prompted the establishment of many venture capital-funded startups with platform-based business models. Established agricultural input firms also saw an opportunity to use their connections with farmers to provide platform-like services. Finally, farmer cooperatives and unique multi-stakeholder organizational forms are developing platforms. The situation is even more complex because of the variety of entry points at which a platform can be introduced. In the following section, we assess the potential of the most common platform ownership models.

6.1. Venture Capital–Financed Startups

The belief that software, big data, sensors, etc., will transform agriculture is now widely shared (Software.org, 2019). Because of these technical improvements, over the past decade, venture capitalists have funded many firms seeking to "disrupt" the food system. In 2018, $16.9 billion in venture capital was invested across the entire agri-food system from inputs to final home delivery (AgFunder, 2019). Although many of these startups focus on agro-biology, most are intent upon applying information technology to problems in farming and the agri-food system, more generally. In the quest for disruption, billions of dollars have been invested in a large number of startups aimed at creating new efficiencies in the agri-food system.[2] AgFunder, an agri-food venture investor and investment data provider, estimated that 1,450 investment deals were concluded in 2018; although this number includes agricultural biotechnology and downstream deals, many had an ICT component, whether software, robots, or drones.

The startups developing platforms in the agri-food system can be divided into two major groups. First, some platforms aim to replace local farm suppliers or provide analytical services to farmers in exchange for data. Second, some downstream platforms aim to intermediate the relationship between farmers and food processors, distributors, and

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[2] Food delivery platforms have spurred the establishment of virtual kitchens, which allow chefs to rent industrial spaces optimized for cooking (Issac & Jaffe-Bellany, 2019). If the amount of food produced in virtual kitchens continues to increase, it could become a new node in the supply chain.

consumers —many of which hope to use digital technology to improve functions such as traceability. For example, "Connecting Food" a French food-tech start-up, provides a smartphone application that allows a consumer to scan a QR code and see every node in the value chain, as far back as the farmer. The app draws upon the fact that at every node in a logistics chain scanners are increasingly used for tracking a product's movement. These movements can then be revealed with a simple app that connects to the cloud where the data is housed.

In another case in France, two agricultural engineers established the firm, Agrifind, to digitize farmers' data. It integrates the various and disparate sources of on-farm data from equipment, Excel sheets, and even paper records. When completed, the now organized data can be monitored on digital dashboards to improve decision making and facilitate benchmarking against other farmers or the various specifications from input firms. The founders' ultimate goal is to create a network of farmers and consultants that share the now standardized data via the internet. While this business model is unlikely to generate significant capital gains, it might, quite effectively, support a community of consultants that could serve the farmer with the platform operating as an integrator and clearinghouse information sharing between the farmer and service providers.

This section focuses on the first group, which would have the greatest impact, if successful. Most startups in this area begin with a particular crop, animal, or service and, because of their wide variety, have many possible entry points for introducing a prospective platform. Unfortunately, the proliferation of startups divides what, in many cases, are already small markets. As with many other fledging platforms, the initial goal is to provide a specific service and, as the platform gains traction, to add yet more services, strengthen lock-in, or diversify the software to apply to other crops. Moreover, because agriculture is a global business, new firms are being formed in many countries. For these reasons, there are a large number of entrants in each niche.

6.1.1. Farmers Business Network

The Farmers Business Network (FBN), which is lavishly funded, is one of the larger platform startups trying to recruit farmers and agricultural input providers to its platform(s). It was established in 2014 in Silicon Valley by two entrepreneurs, one of whom had worked at Google. By 2020, FBN had raised $368 million in venture capital. FBN's founders observed that farmers were the largest and most disaggregated group in the agri-food value chain (see Figure 1) and thus could be squeezed by the larger input firms and food retailers. FBN's business model was meant to address three problems in farming: "farm profitability, inputs market consolidation, and big data" (Cole & He, 2016).

Traditionally, the farmers' information sources for seeds and other inputs have been either large input firms or their local dealerships—both of which naturally favored their own products. FBN's business model is to collect, clean, and upload data streams that farms generate with their precision equipment and/or knowledge about the inputs. This aggregated data is combined with yet other data and analyzed, and the resulting recommendations are given to FBN's customers. FBN stipulated that it would not sell or provide access to farmers' data, and farmers could remove their data from FBN at any time. Effectively, FBN positioned itself as a neutral intermediary whose interests were aligned with those of farmers. For example, FBN provides an online tool to calculate the seeding rate, cost, and yield, which allows farmers to decide the most economical seeding rate for their field (Cole and He 2016). These rates were often lower than seed companies recommended, thereby saving farmers money. Importantly, the more data collected, the more accurate these predictions can be.

As an intermediary, FBN locates agricultural inputs and offers better prices, while earning a commission on sales, while disintermediating local suppliers that are often key firms in rural towns. Effectively, the more users that FBN can attract, the more powerful is its position in relationship to various sides of the platform. By the end of 2019, FBN had added input purchasing finance, crop insurance, and even health insurance. Offering financing is particularly interesting because FBN has a significant amount of data on the borrowers that should allow a reduction in risk. As FBN adds sides to its platform, it has secured more income and data, strengthening its lock-in on existing farmers and farm service providers. FBN's customer base has tripled since 2016, totaling 9,650 farms, with 35 million acres in the US and Canada. More recently, it has arranged contracts with specialty buyers, creating yet another possible revenue source, but it has not yet tipped the market or, in fact, clearly identified its business model. The larger FBN grows the more attractive it will be to the various actors and the more power it will accrue.

The number of startups attempting to become agricultural platforms is huge, even though only one or two usually survive in each market. The large number of entrants is, in part, due to the diversity of crops and variety of business models introduced by these startups. It is unclear whether specialized or general agricultural platforms will perform better. Firms addressing multiple crops may benefit from economies of scope, because of their ability to acquire and integrate various data streams that are not crop specific, such as weather, soil type, water, and nutrients. The cost of computation might differentiate them, as cloud service providers—such as AWS, Microsoft Azure, and Google—offer substantial volume discounts. If economies of scope and scale outweigh specialization advantages, crop-vertical specialists will fail or be purchased by generalists seeking to integrate their knowledge and markets. Also, platform longevity is important for small entrepreneurial firms because if a farm optimizes its operations on the platform of a small firm, and it fails, that firm would be left with an "orphan" software program that, almost certainly, would no longer be upgraded or supported.

The number of venture capital–funded prospective platform entrants is surprising, as agriculture and the food system have been largely ignored by venture capitalists for years. All these startups appear to be losing money and thus are being subsidized by investors. Because venture capitalists only invest with the expectation of return, they must have an exit strategy. This points to a concern among farmers considering joining these small firms' platforms: the possibility that their data will ultimately be transferred to another firm. With the farmer locked in, a new owner might change the terms and conditions of the relationship or have a different strategic relationship with the farmer. Alternatively, of course, one or a few of the startup platforms could become successful, become the dominant powerful platform "winner," and be able to exploit user/producers—as is the case with Amazon Marketplace, Yelp, and Google Search.

6.3. Agri-Food System Incumbent Firms

Existing agri-food firms already have relationships with farmers and, like so many firms in other industries, they aim to servitize their offerings (Roy et al., 2009; Zysman et al., 2011). For them, increasing digitization in agriculture is an opportunity to sell ancillary, value-added services to farmers. One value-added service is to aggregate and process data to provide the farmers with more services. Data management would be an adjunct to their current products and services.

6.3.1. Agriculture Equipment Producers

The two firms that have made the largest investments are John Deere and Monsanto (now owned by the German chemical firm Bayer). Though leaders, they are not the only firms looking to servitize their machinery offerings. Other firms building such capabilities include Kubota, JI Case, and Claas. Farm equipment firms' advantage is that the sensors on their equipment generates an enormous amount of data.

One of the earliest established firms to begin offering platform-like services was John Deere, whose agricultural equipment has become increasingly informated. Further, these machines are increasingly connected to the internet. As machinery moves through the field, the data generated can be transmitted in real time to the cloud, merged with data from other sources, and analyzed. Then, the software gives recommendations to the farmer or, increasingly, directly to the machine. Data generation ranges from ensuring that the combine harvests the field in the most efficient pattern to measuring the protein content of each container load harvested. Prediction of machinery part failure is a vital service because unexpected breakdowns during harvesting are disruptive, as it may require a technician to be summoned while the machinery and the operator are idle.

Equipment makers are centrally positioned because their products are already generating prodigious and rapidly increasing amounts of data, and they can sell analytical services in conjunction with equipment. To further its strategy, Deere established a development center in Silicon Valley (Marr, 2019) and acquired several software firms. The largest acquisition was Blue River Technology, a VC-financed Silicon Valley firm that pioneered machine learning for controlling spraying (Ram, 2017).

The benefit of a platform is offset by the fact that algorithms are proprietary. The increasing informating of farmers' equipment has changed the relationship between farmers and that equipment. For example, when a farmer buys equipment, the mandatory license states that its software is proprietary and cannot be altered or repaired (Wiens, 2015; Wiens &

Chamberlain, 2018). A further concern is that farmers cannot be sure whether recommendations from the equipment providers' platform serve their interests or those of the equipment provider. Similarly, it is difficult for farmers to be certain about how the data collected and uploaded to the equipment firm's cloud will be used. More powerfully, as knowledge about the farm is in the cloud, the role of the farmer is likely to change to monitoring and implementing the cloud's recommendations—increasingly, not only the physical work but also some of the decision-making process will be automated.

Despite their strengths, none of the equipment makers are likely to tip the market toward their platform because farmers who are not using that specific brand of equipment have little incentive to use that brand's services. For this reason, Deere and other equipment manufacturers are vulnerable to an over-the-top strategy. In this case, a digital platform operator (established or startup) secures access to data streams and provides brand-agnostic tools to farmers. Were this to occur, much of the value of the equipment's data would be captured by the platform. This scenario is not impossible. For example, Google is capturing some of the value of vehicle data that might otherwise have gone to auto manufacturers. Google provides Maps, Android, and software for vehicle autonomy, captures vehicle data, and sells it to manufacturers (Windsor, 2019). In sum, equipment makers have the potential to become core platforms in agriculture; however, they face a fragmented market and the possibility that a third-party will become a data intermediary.

6.3.2. Chemical and Seed Industry Incumbents

Efficient seed planting and chemical application can decrease costs, increase yields, and minimize pollution. Because of this, chemical and seed firms see an opportunity to collect and analyze farmers' data and sell back to farmers the resulting recommendations, along with seeds and chemicals. Effectively, farmers would be conducting field "experiments" for the industry, which could then monetize the knowledge gathered over millions of plantings.

In pursuit of these opportunities, in 2013 Monsanto, one of the largest providers of chemicals and seeds, bought the Climate Corporation, a provider of weather prediction and insurance, for $1 billion as part of its service diversification strategy. To increase its functionality, the Climate Corporation platform has added more services, including SeedAdvisor, which recommends which seeds to plant, a service that identifies plant diseases, and a plant nutrition timing service (Bayer, 2019). In 2018, Monsanto announced that the Climate Corporation platform had 100,000 customers and would be opened to ecosystem complementors (Cosgrove, 2018). By early 2020, it had increased from 19 apps, at its inception, to 24. In principle, ecosystem complementors should increase the value of a platform, as they offer innovative services that increase value for users. The road to profitability has not been easy. In 2016, Monsanto suggested that that Climate Corporation would become profitable in 2020 (Plume, 2016); however, it is uncertain whether it has done so.

Agri-input firms have significant advantages in terms of recognition, financial resources, and the ability to package digital services with existing product lines. Yet their platform services have not yet become profitable. Perhaps the greatest difficulty is that farmers suspect that these firms have a conflict of interest.[3] Only the firms know the

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[3] In 2020, a farmer charged the Climate Corporation with sharing his data with the startup Tillable, which aims to connect farmland owners to potential tenants. The Climate Corporation and Tillable had announced a "partnership," which was never explained. Nevertheless, the farmer received unsolicited offers to rent the land at a specific price, and he believed that the offer had been generated from Tillable's access to the data he shared by using the Climate Corporation. The FieldView application tracks the farmer's field from sowing to harvest and

algorithms generating recommendations; thus, farmers cannot be certain whether a recommendation serves the firm, the farmers, or both. Winning farmers' trust is difficult. However, in the case of equipment firms, much of the data they collect is contractually authorized upon farmers' purchases.[4]

6.3.3. Commodity-Trading Firms

Commodity trading takes place on digital platforms that previously were only available to the global agricultural commodity traders such as, Cargill and ADM, and various smaller grain traders, elevators, etc. (Bedford 2019). In October 2018, ADM and Cargill launched a grain marketing digital platform, Grainbridge, with tools that farmers could use. The platform allows farmers to consolidate their marketing and farm operations on a single platform. Grainbridge is open not only to farmers, but also grain companies and buyers (Bedord 2019). Here, the two largest grain dealers in the world have introduced a platform through which farmers and all firms concerned with the post-production part of the agri-food system can transact. This may allow farmers and the giant grain traders to reduce the local elevator to a commodity storage provider by disintermediating its trading operations.

6.4. Cooperatives

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thus has data that enables estimation of the farmer's income and much else about the farm. This use of the data is entirely within the purview of the terms and conditions of the contract with the farmer (Janzen, 2020).

[4] Some rumors say that these algorithms recommend too high seeding rates and too much fertilizer, but little research has been done to verify the accuracy of the recommendations. Given the interests of the firms developing the software and recommendation algorithms, these rumors are unsurprising.

Cooperatives offer an alternative model, as they are owned by their members.[5] If cooperative members decide to share data from their farm and equipment, the cooperative could become a trusted platform with a different governance structure and business model. In this model, cooperative members would have a stake in the platform. Additionally, it can have different goals than a for-profit firm and thus price its services differently. Depending upon the cooperative's goals, if it secures reliable data from its farms, its information could be valuable to other agri-food system actors—and it would have collective power to sell the production data to other food system actors. If the platform was opened to independent app makers, it could also generate income from any apps purchased by farmers. Of course, if an app was particularly valuable, that functionality could be made available by the platform itself. Effectively, in the cooperative business model, data producers provide their data to a platform in exchange for a share of the value generated from their data.

In Europe, agricultural cooperatives are strengthening a collaborative economy framework to better share underutilized and highly expensive equipment, as well as immaterial resources through learning, sharing specific knowledge, good practices and experiences. While the concepts of collective learning and sharing have always been attached to cooperatives business models, digital platforms and software are making these practices easier, faster, less expensive, and thus, aiming to introduce platforms to increase community value creation (Como et al., 2016; Filippi, 2014).

InVivo, the enormous French cooperative of cooperatives, actively invests in digitization and provision of the software, which provides the basis for the data collection necessary to introduce a platform. For example, it purchased Smag, a farm management software firm that owned Agreo and Atland, which are cloud-based agronomic data

[5] Trebor Scholz (2016) has written about platform cooperativism, which refers to cooperatives organized entirely online.

management software programs (In Vivo, 2016) that can be monitored from a farmer's PC or smartphone. In 2019, InVivo launched the platform Aladin.com that allows vendors to offer a wide variety of products and services, including those that are useful for alternative and sustainable products and practices. InVivo offers various kinds of software for precision farming that allow the analysis of field sensor data, seed-sowing densities, and soil fertility to enable the application of fertilizer at a variable rate—which all save time and costs. Finally, in 2017 InVivo opened an incubator to develop novel digital applications for agriculture, food, and the wine industry.

In principle, it should be less risky for a farmer to provide data to a cooperative because even if it uses that data to increase income, it returns the income generated from the data to the farmer. In contrast to for-profit input suppliers that provide the platform as an adjunct to their main business line, cooperatives should have fewer conflicts of interest. For example, a cooperative has little incentive for recommending unnecessary repairs or chemical treatments to increase income. Additionally, a cooperative can only be sold with the consent of its members. Consequently, farmers have input in decisions about transferring data ownership.

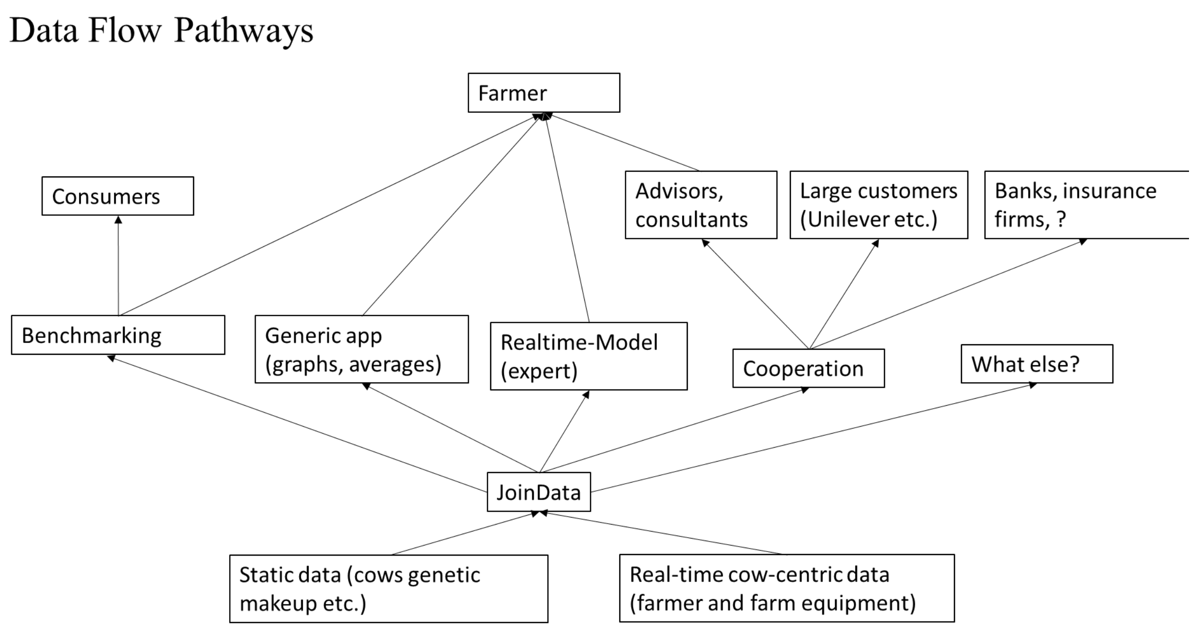
6.5. Specially Formed Entities

The opportunities and difficulties in organizing effective economic arrangements to secure data sharing have led to experimentation with new business and organizational models. The goal of these models is to secure the benefits of platforms without losing control to a platform owner.

For example, in the Netherlands, a consortium of groups formed "Smart Dairy," a platform to connect dairies, input suppliers, and milk purchasers. Smart Dairy initially consisted of the Dutch national research organization VNO, local universities, dairy cooperatives, dairy equipment suppliers, and, initially, seven dairy farms. Their goal was to create a software platform on which farmers could contribute their data and view relevant information with a single dashboard. The analytical software would provide farmers with recommendations at the level of individual cows.

In 2019, the project and its software were turned over to a newly formed clearinghouse platform, JoinData, which operated a data-broker platform business model (see Figure 5). As data brokers, farmers and firms could transfer data to each other, because JoinData never owned or stored any data, acting merely as a clearinghouse. The software and platform have been successful at connecting approximately 15,000 Dutch dairies. Using this model, farmers can share their data with any interested parties: banks, insurance firms, production cooperatives, dairy machinery firms, and milk processors. In principle, the model should result in significantly improved recommendations and analysis. Like the startup, Agrifind described earlier, Smart Dairy operates as a clearinghouse, not a data repository.

Figure 5. Data Flow Pathways for the SmartDairy Project



Source: adapted Aaker 2020

Another European example is in Germany, where farmers are repurposing a variety of organizational models for agricultural machinery-sharing companies (the Ring model) to also provide data aggregation and analysis services. By acting together, farmers can purchase high-cost machinery (Hastedt, 2016), which can collect data that provides individualized summaries and recommendations to farmers/customers. In this case, the machinery provider aggregates and analyzes the data for all the farms it serves (Giesler, 2018). In the process, the machinery-sharing organization gains a potentially significant competitive advantage over farmers and others in the value chain and presumably could sell them new recommendation services. Effectively, these service providers could evolve into a platform or a data intermediary that offers services from third-party vendors.

Platforms can also be developed with other business goals, such as, improved ecology and sustainability (Dabbous & Tarhini, 2019). For example, in France, co-farming associations, firms and digital platforms are being established to enhance data sharing between the agri-food system actors in order to increase sustainability. For example, the Chamber of Agriculture established NumAgri (Numagri, 2019) as platform for sharing data with other farmers and trusted organizations. Another platform, Num-Alim (Ania, 2018), encompasses post-harvest firms and provides an "identity card" to each product in the form of a QR codes that consumers can scan which will provide information on the origin, ingredients, nutritional value, and environmental impact of that product. To improve the impacts and performance of these platforms for every node of the food value chain, the "Ferme France" association (see. Ferme France, 2019) created a platform to the interest in monitoring the societal impact of food production and consumption. This platform assembled a diverse set of stakeholder organizations including those representing farmers, food industries, distributors, consumers, agricultural unions, cooperatives, and restaurants to develop an index based upon six sustainability dimensions -- environmental impact, animal well-being, fair prices for farmers and consumers, ingredient\ origin, nutrition/health impact, and traceability. These French efforts attempt to build collective platforms that integrate the various nodes of the agri-food system to address the challenges the system faces.

In this section, we discussed possible ways to assuage the fears of value chain actors regarding how platforms might be deployed. The info-broker model is one way to solve the problem, but farmers have been reluctant to share information. In Germany, the Ring model is adapting to the digital era, as the Ring's machinery is already in the field collecting data, and the machinery operator uses the data to provide advice to the farmer. In this case, farmers receive an immediate return on their data. In contrast, the JoinData model shares farmers' data with others who have conflicting interests. The French models are macro-level, top-down models that seek to create multi-stakeholder consensus and solutions. This section shows that there is significant organizational experimentation concerning how to extract value from farmers' data and distribute it among key stakeholders.

6.6. Existing Digital Platform Giants

Agriculture has attracted Google, Microsoft, and IBM to invest in building capabilities in agriculture. For example, in 2019 IBM introduced Watson for predicting the best date for activities, such as planting and harvesting (Dignan, 2019). Watson is targeted at large agribusiness firms and consultants that advise farmers, rather than the farmers themselves (Miller, 2019). More recently, Microsoft introduced FarmBeats, an application on its Azure cloud computing that provides farmers with data, though at this point it is not commercialized (Wiggers, 2019). Google has also expressed interest in agriculture, perhaps most concretely, through investment in a variety of agriculture startups, including FBN (Troitino, 2018). Given Google's capabilities, its ultimate goals are more difficult to predict, as it already has Google Earth and Google Maps, as well as access and the ability to analyze remote-sensing data in sophisticated ways. Thus, the gathering and analysis of farm data would be technically trivial. Google Android and Maps are integrated into an increasingly large percentage of the world's automobiles, so why not farm equipment? These internal capabilities provide it with complementary assets that would facilitate its entrance to agriculture as a platform or supplier of services.

The final major platform firm that might enter agriculture is Amazon, which already has a significant presence in food distribution through its Amazon Fresh and Whole Foods subsidiaries. Amazon is hiring professionals to offer cloud computing to firms in the agri-food system. However, this strategy does not appear to be aimed at developing a platform but, rather, to sell its cloud computing capability (AgDaily, 2019). At this time, the dominant platform firms appear to be more interested in providing cloud computing services to agri-food systems than trying to establish a platform that directly aggregates farmers' data and connects various nodes in the agri-food system.

The bewildering variety of organizational forms for implementing platforms in the agri-food system suggests that no dominant business model has yet emerged. However, the decision to adopt a platform is significant, as adopters must optimize their operations for the platform.

7. The Impacts of the Widespread Adoption of a Platform

The impact of platforms on agriculture is, at this point, minor, as no business model capable of tipping the market has emerged. For this reason, in the following sections we speculate on key social relationships that might be affected.

7.1. Data Ownership and Usage

Whoever holds rights to data will capture its value. In the consumer internet, platform users surrender substantially all their rights. In business-to-business relationships, firms are warier of providing data, as doing so is assumed to have value and exposes their internal operations. For example, a combine's yield, moisture, and protein sensors provide exact information on the productivity of a field and the quality of output (Miles 2019). The aggregation of this data with that of other farmers, grain elevators, and food processors can provide remarkable insight into, for example, supply and, therefore, prices. Similarly, data on seed variety plantings, combined with information on the weather, chemical application, irrigation, and the yield, could be of great value to seed breeders. If this data is aggregated over many farms, it is possible to use sophisticated statistical analysis and machine learning to gain new insights that could increase productivity. Data regarding the torque required for a tractor to move through certain types of terrain may be of little value to a farmer but extremely useful to a tractor designer or tire manufacturer. For all participants, the question is: who will capture the added value? Although the data is a by-product of agricultural activities, it is also a record of actors' activities (Bronson, 2018).

The ownership and use of farmers' data is becoming an issue. In 2014, national farmer organizations and leading agricultural data firms in the US, such as John Deere, the Climate Corporation, DuPont Pioneer, and Dow AgroSciences, negotiated a voluntary agreement called "Privacy and Security Principles for Farm Data." This agreement outlined expectations regarding the ownership, portability, disclosure, use/sale, and retention of data as well as contracting practices (Sykuta, 2016). In the food system, as in other value chains, the question will be how to monetize the data generated to improve business processes, whether that means "wrapping information around core products and services … or selling information offerings to new and existing markets" (Wixom & Ross, 2017 p. 10).

7.2. Platforms and Agricultural Labor

The automation and digitization of agricultural equipment already affect work processes and are expected to decrease the need for on-farm labor. The introduction of new technologies may replace some tasks, while creating others; it could deskill, augment, or even require more training for workers. In terms of work processes, Mateescu and Elish (2018: 5) found that data-intensive technologies, such as crop management tools and "smart" tractors, require new work routines and changes in physical infrastructure, such as securing rural broadband internet and reorganizing the layout of barns or fields to facilitate optimal sensor readings. In addition to these physical requirements, cultural shifts in the business logics of family-owned farms are also required. For instance, a physical field must now be conceptualized as a complex dataset to be managed using other digital information and digital tools.

Estimates on the general employment impacts of automation range from apocalyptic, with 47% of US employment at high risk of displacement (Frey & Osborne, 2018), to a far more modest, displacement of 15% (Manyika et al., 2017). Further, Frey and Osborne (2018) suggest that farmers and ranchers, perhaps because they own the farms and can thus make management decisions, have a low likelihood of displacement, whereas many others in the food system, such as operators of food cooking equipment, fast food cooks, and farm labor, have a higher risk of displacement. Of course, the long-run trajectory in agriculture is the displacement of farm labor. This is despite the fact that currently, the US and many other countries have labor shortages in farming (Charlton et al., 2019). This is increasing interest in automation. Some micro-level studies that the demand for labor may decrease. To illustrate, a study in Canada regarding the impact of milking robots found that they enabled the farm to decrease the number of employees, thereby saving money (Tse et al., 2018).

It is possible that the displacement of farm labor could be significant (Rotz et al. 2019). For example, drones are small, maneuverable, and capable of operating in all sorts of terrain, even where only hand spraying is feasible (Teigler, 2019). These drones could replace both high-skilled crop-duster pilots and low-skilled hand sprayers. Moreover, their use could also have significant social benefits, as it could severely reduce worker exposure to harmful chemicals (Hill, 2018). Of course, it is also possible that pesticide use could increase. In contrast, complete automation of harvesters could reverse the inexorable adoption of larger equipment, as smaller robot tractors could lower labor costs and decrease the risk associated with the breakdown of a large tractor. As a result, smaller, lighter equipment could be deployed, which would be less damaging to fields in terms of soil compaction (Karsten, 2019). Such equipment might be simpler, thereby reducing costs and risk related to equipment failure.

The ultimate impact on employment is indeterminate. For example, if drivers are replaced by automated tractors, would the demand for agricultural software developers outnumber the displacement of farm labor? Of course, the new workers could be from an entirely different labor pool. The introduction of tractors in US agriculture in the 1920s to the 1940s led to farm consolidation and displacement of massive numbers of agricultural workers (Kenney et al. 1989). Instead of remaining in agriculture, these workers moved to cities to work in factories. Finally, in some countries, the adoption of automation is being hastened by labor shortages due to reduced immigration (Taylor, 2017).

7.3. Impact on Farm Size

In the US, over the past 30 years, the size of farms has markedly continued to increase (McDonald & Hoppe, 2018). As during the previous mechanization wave, concerns have arisen that ICT will have a significant scale bias. The impacts of digitization and platformization are difficult to predict. One recent study suggests that ICT adoption will encourage further consolidation, resulting in larger farms and firms in the food system (Poppe et al., 2017). However, the increasing sophistication of tractors and combines has raised their price. Additionally, the belief that software and robots will replace labor might lead to greater capital intensity. Of course, ICT might lower the cost of entry and production through equipment automation, in the same way that drones are less expensive than piloted planes.

7.4. Disintermediation of Local Farm Suppliers and Distributors

The emergence of platforms as intermediaries has had a devastating impact upon local retailers. The consolidation of farms has been accompanied by a parallel consolidation of farm input suppliers. One obvious opportunity for platforms is to disintermediate local farm input suppliers by allowing farmers to buy directly from input producers. Alternatively, independent platforms, such as FBN or those offered by InVivo, could increase transparency, improve price discovery, and allow farmers to buy directly from the lowest-cost distributor (Gullickson, 2018). Digital intermediaries, such as FBN, can match input vendors with farmers—especially for highly standardized products. One farmer was quoted as saying, "it [FBN] was a better price than where I normally buy, which was hard for me because we've been pretty loyal to our local retailers" (Konrad, 2017, p. 1). For certain inputs, disintermediation may be easy, but it may be more difficult for others, such as machinery, for which after-market service is important.

On the downstream side are intermediaries, such as distributors, retailers, and farmers' markets positioned between the farmer and consumers, some of which may be replaced by a platform. The most salient example is Amazon, which entered the grocery business through its purchase of Whole Foods and Amazon Fresh grocery delivery. Otherwise, Amazon has no connection to farmers. Many digital platforms are hoping to intermediate between farmers and urban consumers searching for organic or locally sourced foods. Digital platform firms appear to be experimenting with methods to connect farmers and local consumers, but little evidence indicates that these business models are having significant success.[6]

7.5. Assisting in an Ecological Transition?

By enabling increased precision, digital technologies provide great opportunities for advancing an ecological transition (Klerkx et al., 2019). Precision agriculture has the ability to deliver the right dose of chemicals to the right location in a field, which might dramatically decrease the total amount of crop chemicals used. Irrigation could become more efficient, as image recognition is increasingly able to predict a plants' need for water and provide the exact amount necessary, replacing the wasteful practice of watering an entire field equally. Furthermore, the use of image recognition software and robots could enable weeding that uses no chemicals at all. Digital technologies can increase traceability, thereby reducing the need for food recalls that result in waste. Given the pressure to become more sustainable, digital technologies enable greater sustainability.

8. Discussion

The petrochemical revolution transformed agri-food systems. We believe that agri-food systems are now on the verge of another transformation driven by digitization. Precision agriculture is made possible by modeling agricultural production activities in software and capturing data that can be analyzed by algorithms. Whereas fields were previously treated in the aggregate, today granular data and software-enabled precision enable more precise treatment of fields. For certain valuable tree crops and wine grapes, the ability and cost of data gathering and analysis have decreased to the point that individual plant care is possible.

[6] For example, LocalHarvest operates in all major US metropolitan areas and provides a platform and software for managing the relationship between consumers and local family farms.

The cultivation of row crops has advanced from uniform treatment of entire fields to partitioning fields into unique zones to be managed differentially.

There is already significant evidence that informating agriculture is changing farmers' work processes (Mateescu & Elish, 2018). For example, the drivers of contemporary combines are charged with monitoring their operation and making decisions based on visualizations and recommendations generated by algorithms that they may not fully understand. Much of the data generated by farmers' equipment may have limited value for them—in the same way that data generated by an airliner's jet engine may have greater value to the jet engine producer than the airline. For farmers, data might have the highest value after it is pooled with data from others and processed to provide them with recommendations. Furthermore, data may be of value to third parties, such as banks or insurance firms. The organization sitting at the nexus of all these data flows would be a panopticon and thus have an advantage over every other actor. Thus, for all actors in the agri-food system, ownership of data is fraught with possible benefits and hazards (Ellixson, Griffin, Ferrell & Goeringer, 2019).

The promise and potential of digitization and platformization of agriculture and food industries are immense. The existing actors and new entrants into the agri-food system will have to develop business models that enable data sharing. The owner of the platform is likely to develop inordinate power when compared with the other actors in the system. And yet, the structure and even number of platforms that will survive or come to dominate remains unknown. Ideally, the platforms that succeed will aggregate data so that its value can be exploited while ensuring that the data providers are compensated and assured that data will not be used in ways that are inimical to their interests.

9. Conclusion

Whether and how platforms are adopted and organized in the agri-food system are difficult to predict, as the internet of things dramatically increases the amount of data generated. Digitizing and platformizing the entire value chain from agricultural inputs to final consumption would create greater efficiency. Additionally, verification, traceability, and transparency, in conjunction with machine learning and other techniques to improve precision, should create greater efficiency and, presumably, profits. Importantly, the platform must determine how the gains should be distributed among all the actors in the value chain.

Digitization has myriad implications with respect to sustainability. The ability to characterize a field or an animal's actions at a more granular level introduces significant opportunities to optimize inputs. The greater the integration of data is across the entire agri-food system, the greater the efficiencies are. Further, digitization and the use of remote and land sensing allow the identification and measurement of agricultural run-off, thereby improving pollution identification and legal enforcement. The key to improved sustainability is sharing data. Yet doing so has already proven difficult in industrial value chains, except in supplier chains with a dominant player that can force data sharing. Machine learning applied to farm data might be used to produce more ecologically benign and nutritional foods. But if the most powerful actor desires maximum profitability, then the system will be engineered to deliver that goal over less profitable but more ecologically benign practices or more nutritional foods.

As all of the activities in the agri-food system become more software intensive, without the creation of significant open source software, power and value added will go to the software providers and the owners of the algorithms analyzing the data and making recommendations. In a world run by software, those who use it must have the confidence that the software recommendations are in their interest and not solely in the interest of the software developer owner. An organizational model that can ensure the interests of all stakeholders is vital. The alternative is a dystopia in which a few platform owners, or even a single one, dominate the agri-food system and extract value from the other stakeholders and, in particular, farmers.

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