A European Perspective on the Economics of Big Data

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Modern information-based technologies, such as self-driving tractors, GPS (global positioning systems), robot milking machines, automated egg production, drones, satellite data and social media, will change farm practices and agricultural structures and contribute to the prosperity and resilience of farming systems. Food chains will not only become much more data-driven but will also move away from a situation characterised by a low level of data integration. This will have a significant impact on such issues as sustainability, food safety, resource efficiency and waste reduction.

The economic and social effects of such developments are still to be explored. At first sight they could lead to more closely integrated supply chains that make the farmer act simply as a franchisee with limited freedom, but the opposite could be true. Farmers could be empowered due to greater transparency and easier options for direct sales in consumer food webs (using social media and smart solutions for the ‘last mile’ delivery). Therefore we can see conflicting pressures between the globalisation and localisation of supply chains.

As with previous technological developments, not all farmers will invest in new skills and where technologies are labour saving, farms will get bigger. Some farms or regions will become less competitive if the basic infrastructure (e.g. broadband internet or GPS systems) is lacking. Competition between advisors could increase, if they are able to serve farmers digitally. In addition, part of such value added activities may move from the most remote rural areas to regions with clusters of knowledge and could also become more international in nature.

A major issue is that information and communication technology (ICT), combined with higher food prices and demographic changes could fundamentally shift the competitive advantage from family farms to more industrial holdings, leading to radical structural change in agriculture.

Introduction

Over the last decade the use of information and communication technology (ICT) in the farm sector has increased significantly (Henten et al. 2009). Poppe et al. (2013) highlight a range of areas where ICT has been successfully applied. These include:

- Use of satellite data to precisely control field operations, making it possible to increase labour productivity by increasing the size of machines.
- Processes for combining remote sensing data on crop growth and farm data on crop interventions (and ex-post yields) leading to more informed decision-making.
- Wiring of glasshouses with sensors and computers to steer the production process in an optimal way.
- Introduction of robotic milking on family farms in North Western Europe where labour is expensive and farmers are highly educated.
• Increased use of sensor technology with cows increasingly measured as intensely with sensors as athletes. Sensor data are much better than the human eye at predicting diseases (such as lameness) or the optimal time for insemination.
• Tracing and tracking have become standard in agri-logistics.
• Retailers are increasingly using apps on smartphones to support consumers and to increase brand loyalty.
• Establishment of online shops by farmers due to sharp falls in prices of delivery services as a result of liberalisation of post and parcel markets.

This list of examples shows that several participants in the food chain are already making advanced use of ICT and are experimenting with new developments. However this is just the start of what could become a revolution in agriculture, not unlike the wider adoption of the tractor and the introduction of pesticides in the 1950s. It will change the way farms are operated and managed and it will change both farm structures and the wider food chain in unexplored ways – just as in the 1950s the extent of the changes in the next three decades could not be foreseen.

The key to this new revolution is unlocking the potential of the data generated through the application of ICT. At the present time, for example, farm data are still rarely shared with advisors or the processing industry, analysed by intelligent software or combined in regional analysis and advice. With the Internet of Things (IoT) (using data from sensors, machines and other devices) we have entered the era of big data. Especially in sectors with many small players, like agriculture, there is a need to invest in software that makes data seamlessly available to business partners and government agencies – like large firms already do internally in their enterprise resource planning (ERP) systems. These firms now have a need to connect to the digital data of farmers and logistic service providers. This brings us to the research question of this paper: how will big data, exchanged between farmers and their business partners change the nature of farming?

To address this question the paper is structured as follows. The next section considers ICT in the food chain and highlights how it has resulted in large amounts of data that are poorly integrated. It then introduces the project FIspace as an example of how the European Union (EU), in a public-private partnership construction – the future internet (FI-PPP) – is developing data exchange platforms to overcome the difficulties with integrating data across the supply chain. Following this, the paper discusses three areas where changes in farm systems may be induced by a seamless exchange of (big) data in food chains. These are: the market for apps and data; the evolution of food chains; and the organisation of the farm business itself. The final section pulls together the analysis to draw conclusions.

The Data Challenge

ICT in the food chain

Currently food chains are confronted with several business issues and societal challenges. In terms of new business models these include: advice being increasingly bundled with technology; precision farming; better service concepts in logistics; segmentation in the food industry to cope with heterogeneity in farming and among consumers; and consumer decision support (Poppe et al. 2013). Figure 1 summarises the extent that data and ICT contribute to the development of new business models and the relevant policy challenges that are addressed.

What is needed for many ICT-based solutions to address the challenges in the food chain, as highlighted in Figure 1, is a better exchange of data between business partners (and with the government). In the near future, Facebook-like data exchange platforms will make it possible to move data seamlessly from one partner in the food chain to another. A key issue is whether these systems will be proprietorial (developed, for example, by the global players in the food chain) or whether they will be more ‘open’ systems. An example of the latter is described in the next section which highlights how the EU’s FI-PPP is developing the infrastructure for data exchange.
Data Exchange with FIspace

Cloud technology (that gives people access to their data from different devices and places) also makes it easier to share. Open data (in which governments or others share their data free of charge) can be seen to be an example of such exchanges. Together with the Internet of Things this contributes to the era of big data.

Within an organisation these developments can be implemented relatively easy. Enterprise resource planning systems (ERPs) and customer relation management (CRM) software can be extended. However, between organisations it is more problematic, as the so called ‘interoperability’ of data and information systems is very low. This holds for SME-to-SME or SME-to-government communication as well as SME-to-big company communication. Imagine for instance the challenge for a large dairy cooperative that wishes to exchange digital data with 10,000 farmers, or a manufacturer of milking robots that wants to monitor operational data from products that are sold to farmers.

The issue is even more complex, if one realises that the data exchange between, for example farmers and their cooperative or robot supplier, will lead to digital data that has to be used by third parties. This will mean accountants, for example, require access to the electronic invoices of the cooperative, whilst the farm management system, the vet and the herd book needs access to the data from the cows milked by the robot.

Data needs to be exchanged with common standards and an Agri-Business Collaboration and Data Exchange Facility (an ABCDEF) is required as an infrastructure for this data exchange. This is a common pool investment, and the EU has understood that it should help to build such infrastructure in the FIspace project of the FI-PPP.

FIspace (www.fispace.eu) can best be imagined as a business-to-business software tool comparable to LinkedIn or Facebook – a social media service that connects companies (instead of persons) and their operations. Businesses can contact each other (or a government agency) and start a collaboration. They could, for instance, detail a contract and specify which data they would like...
to exchange, the standards the data will conform to (eg EDIFACT\textsuperscript{2} or XBRL\textsuperscript{3}), and under which circumstances the exchange will occur. This could be data like invoices or delivery notes, but also Internet of Things data that allow for real time tracing and tracking.

Sharing such data should be as easy as uploading a photo on social media, but here the analogy with social media in private life ends. Companies may be more willing to maintain control of their data, specifying access and use rights, and whether their data can be centrally stored with a third party. Companies typically have their own databases (those CRM and ERP systems or simpler farm management systems) and use web services to connect them to each other.

SMEs can use specialised software applications to store their own data ‘in the cloud’. As companies wish to maintain control of their data, Flspace does not store the data exchanged between companies. It only stores the links between companies and the rules that have been specified to share their data.

Another difference between companies and consumers is that companies need much higher standards of security for their data management. The future internet technology on which Flspace is built makes this possible (eg by encryption and selective access rights). Once the data is available in a digital form it becomes attractive to employ the data in business processes using special software, similar to how apps on mobile telephones or tablets enrich external data. For this reason, Flspace has an app store in which app developers can market and sell their software (see Poppe and De Smet, 2013, for more information on FI-PPP and Flspace).

Essentially, such ABCDEF software makes it possible to give business partners (and governments) access to farm data and farmers to combine data from different sources. This has important economic consequences and will improve the sustainability of the food chain. Whilst recognising that the impacts of this exchange of data are wide ranging, in the following sections three areas are chosen to illustrate some of the changes that will occur. These are i) the impact on the market for farm management software, ii) the changes in the food chain, and iii) the organisation of the farm itself.

The Market for Software, Apps and Data in Agriculture

There is significant diversity among European agricultural holdings in terms of farm type, size, geography, language etc. Network and communication infrastructures, software, service and media technologies systems throughout the agrifood chain are predominantly produced and distributed on a national or regional basis, or by manufacturers in relation to specific subsectors. The companies selling farm management software generally emerged in the 1980s with the introduction of the personal computer (PC) and are actively operating as SMEs in national markets. Their revenue stream is often relatively small, based on maintenance contracts from a declining number of farmers. However, due to software trends (like cloud technology) they are confronted with rising costs, especially if they have to build in new functionality to incorporate Internet of Things data as it becomes available.

This situation increases the costs of producing devices, software, service and media technology systems, it slows down the introduction of new products to the market, and it causes frustration among the stakeholders throughout the agrifood chain. Not only is data sharing between systems almost entirely absent, but there is also little tradition for incorporation of standardised components into the systems. However, ABCDEF’s like Flspace and future internet technologies (as introduced in the FI-PPP) will change this.

Flspace establishes an infrastructure to exchange (or better, to give access to) central data for software-providers. In this cloud-based business-oriented social media the users (like SMEs and farms) can make the data they control available to apps. These apps can be bought (or downloaded free) in an app store, like those currently available on mobile phones.

\textsuperscript{2} Electronic Data Interchange For Administration, Commerce and Transport

\textsuperscript{3} eXtensible Business Reporting Language
Apps will replace some of the functionality of farm management information systems (as well as adding new functionality). Such apps can be built more cheaply with future internet standardised software-components (so called enablers, like a standard component for a web-shop or to run an auction). This implies that app builders do not have to worry about organising access to the data, as long as they use the data standards by which farmers access their data.

As FIspace is a European or global service, this also means that app builders have access to a large European or global market with many more potential clients than software makers have in their current national markets. Besides specialised apps for sale, governments, researchers, non-government organisations (NGOs) or businesses in the food chain might want to provide services and advice to farmers free of charge in an app. For example, it may be a way for governments to communicate public-good type advice (around animal health and welfare or the environment, etc) to farm businesses.

For current farm management information systems (FMIS), this means breaking up their software into one or more apps that help farmers in entering farm data manually, if needed in sync with data exchanged by the farmer (eg taking the data from delivery notes or invoices on pesticides bought and adding the information on the use on a particular crop in a particular field by entering additional data on a mobile telephone using its location service) and into apps that help farmers interpret the data.4

These technological developments replace a market for farm management software with a market for ABCDEFs (with FIspace as a first product in this category) that have an embedded market for apps. An intriguing question is whether or not this will also lead to an embedded market for data. Currently nearly all data are exchanged free of charge, exceptions being ticker data from stock markets and marketing data (eg shopping pattern data). In agriculture, data are used to prove that products are of a different quality (eg organic) and lead to a higher price for the product, but data itself is not priced.

Changes in Current Food Chains

A seamless exchange of (big) data will have a significant impact on food chains. Important changes include: i) the end-to-end tracking and tracing and virtualisation of food chains, and ii) the emergence of direct farmer-consumer markets supported by ICT.

The most obvious change is that tracing and tracking, not only of products, but of the full history of their treatments will become a reality. This will lead to more influence from business partners on farm decision-making. This could be through the provision of advice or by tighter contract stipulations. In addition, service level agreements by advisors or, for example, companies that sell machines are possible.

With cloud-services like FIspace the tracing and tracking of products becomes much easier. Business partners can share the data on the history of the product with the buyers at the next stage of the chain. This implies that apps for consumers can provide information on the product, all the way back to the grower of the product and its seeds. This even holds for complex products like pizzas that are made of many ingredients.

Such data can also be used for real-time virtualisation. Through sensing of physical objects at different levels of aggregation (eg product, box, pallet, container, truck), rich and globally accessible virtual representations of these geographically dispersed physical objects can be created (Verdouw et al. 2013). Virtual objects must provide multiple views for different users who have distinct requirements. Visualisation plays an important role in creating views that are experienced by human users as reality.

As in a kind of second life environment one could ‘walk through’ the supply chain and see what is going on at any stage at any moment, and also place it in the context of its historical development (Poppe et al. 2013). Whilst this may be fun for children to see where their milk came from, or to see where the bottles of olive oil ordered online are en route to the consumer, real time virtualisation primarily has practical use in business processes. Examples include applications

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4 See Kaloxylos et al. (2014) for a first example of such a future internet based farm management system.
for advanced visioning (e.g., high-speed/low-cost solutions, three-dimensional, and of internal features such as ripeness of fruit) for quality inspection of food and flowers based on (mobile) augmented reality.

The exchange of data will also make it possible to add more (computer) intelligence to the chain, including monitoring, problem notification, deviation management, planning, and optimisation. Examples of food-specific intelligence functionalities are apps for early warning in case of food incidents or unexpected quality deviations (e.g., temperature or humidity changes), advanced forecasting about consequences of detected changes by the time the product reaches destination (e.g., dynamic simulation of best-before dates). This could also lead to dynamic pricing and less waste.

These developments will contribute to greater levels of sustainability, where food processors, retailers, and consumers can trace products to their source and investigate the different aspects of sustainability of individual products or batches of products. Ultimately, they can give feedback to farmers or penalise the least sustainable producers.

It is unclear to what extent the tracing and tracking as well as the real-time virtualisation services will be provided by current service providers, including ICT suppliers and auditing firms, or if new types of service companies will be established. As transaction costs change with such ICT solutions, it is likely that the way the food chain is organised will change too. In some cases, this will even lead to totally new chains that replace current ones. For instance, auctions could go online, making it possible to sell the fish when the fisherman’s boat is still at sea.

Another example is direct marketing between farmers and consumers. There is an increased interest in ‘local’ as opposed to the dominance of ‘global’. Food has always been a means for consumers to profile themselves in a social environment, but in the last decade food culture has clearly grown in importance. Sustainability aspects are much discussed, by chefs as well as large segments of consumers and NGOs. The consumer market has become more heterogeneous and so has the farm sector. Reducing market interventions in the Common Agricultural Policy (CAP) in Europe gives farmers more freedom to produce as well as exerting pressure to choose their own strategy. With heterogeneous consumers and farm systems, it becomes attractive to search for methods to match the demands of those segments (Poppe et al. 2013).

By reducing transaction costs, ICT enables collaboration in regional clusters such as local-for-local food webs that deliver local, often organic, food products to local consumers, restaurants or health care institutions. The internet plays an important role in these clusters by matching local demand with supply and subsequently managing the last-mile logistics. The liberalisation of postal markets and the restraining of labour costs, especially for low-paid logistics, have supported the trend towards an increasing market share for online shops.

Changes in the Scope of the Farm and Farm Organisation

As with previous technological developments, not all farmers will invest in new skills (Läpple et al. 2015; Islam et al. 2013). To what extent these developments in ICT will exaggerate differences between farms is an interesting question. For example, will they be scale-neutral or benefit larger farms more than smaller ones – which has been the case with innovations in the past, especially ones that improve labour productivity.

The devices (like smartphones and tablets) involved in data sharing with ABCDEFs like Flspace, as described above, are not very costly. The breaking up of complicated farm management systems into apps, based on standard components and marketed more broadly (e.g., Europe instead of one national market), makes software cheaper. This suggests that the trend to big data may not be detrimental to the position of small family farms. They might even benefit more than large farms from options for direct sales in consumer food webs, using smart solutions for the ‘last mile’ delivery, as described in the previous section.
However, this picture could be too optimistic for the small farm. In existing food chains farmers have to invest in data gathering and FMIS to satisfy demands from food businesses and retailers for tracing and tracking and quality assurance schemes like GlobalGap. As agricultural processes become more programmable (and are less dependent on unpredictable natural events), as investments are less general in nature but become more tied to specific products (such as know-how on how to grow organic broccoli) and marketing is a joint effort of a producer group and a retail chain (such as with some new apple cultivars), more complex organisational forms appear.

In part these complications arise because relying on the spot market is a major business risk for the parties in the food chain (Boehlje 1999). Such movements away from commodity markets towards more complex organisational forms favour larger farms – it is as easy to contract 1000 tonnes of potatoes as 10 tonnes. In the end this could lead to more closely integrated supply chains where the farmer acts as a franchise taker with limited freedom. There are likely to be ABCDEFs like Flspace that could counterbalance this situation to some extent, as they make a farmer less tied to the software of a supplier or food business, and reduce the switching costs between chains.

A second unfavourable aspect for small family farms is the fact that the monitoring of agricultural processes will greatly improve. To understand why this may work against family farms we have to address the question why we have family farms at all, and not large companies like in food business, retail or other sectors.

Markets generate income by making it possible to specialise, particularly in roles like farm manager, farm labourer, investor and land-owner. In family farms, farmers combine several of these roles (especially those of management, investor-owner and labourer) when the market provides insufficient incentives to specialise. There are two explanations why these incentives are too low.

The first is that the risks are too high and the profitability too low. This leads to low levels of interest (or too high profitability demands) from outside investors. Therefore large farms where farmers manage a number of specialised labourers (like in a plantation) cannot compete with family farms that accept a lower profitability (as long as it satisfies their income needs). The low profitability and structure of small farms is explained by the (inefficient) working of the labour market. For example, farmers do not leave the sector easily as this may lead to having to move to urban areas or giving up tax advantages, for example. This results in farmers having low opportunity costs.

The second explanation, put forward by Allen and Lueck (2002), deals with the fact that agricultural production processes are difficult to monitor. This leads to moral hazard and an agency problem. For example, the investor cannot monitor the farm manager and is faced with the question whether the disappointing results are due to weather or diseases as the manager claims or whether they are a result of poor performance by the manager. In the same way, a manager may wonder if the farm worker is working conscientiously in the field furthest away from the farm office. This Coasean way of thinking implies that the transaction costs of monitoring to address the agency problem determines the organisational form. It is therefore a trade-off between specialisation via the market or addressing moral hazard problems through doing it yourself.

Both theories that explain the strong position of the family farm also imply that some future trends may favour large non-family farms. In the first case, increasing prices and profitability make it more attractive for outside investors to invest in farming. This is a trend clearly seen in the Ukraine, for example. Western Europe’s access to cheap labour from Eastern Europe also leads to more specialisation. In the second case, ICT is a clear threat for the family farm as with ICT monitoring options increase considerably and many agency problems can be solved.

Last, but not least, there is the threat of another change to the organisation of the farm (and rural areas). Some activities could disappear from the farm when they become automated. For example,
sensors that measure an animal’s activity can determine when cows should be inseminated for reproduction purposes. If this sensor then sends an SMS, to the vet for example, the role of the farmer is bypassed. Taking this idea further could imply that some value added activities, like advice, move from the most remote rural areas to regions with clusters of knowledge where they are provided by ICT. For example, it is more likely that the apps for the farmers based in Europe are built in Berlin or Wageningen rather than in a remote area in Bulgaria.

These effects are probably stronger in propriety systems that are linked exclusively to the ERP system of a big food business, retailer or supply company than in a system where switch costs are low. This raises major questions as to whether the already significant imbalance of power in the food chain (see for example Renwick et al. 2012) will be further exacerbated. Such concerns may mean that an ABCDEF like Fspace should be favoured over a propriety system, especially if one wants to support family farms. However, the analysis does suggest that the era of big data is probably less innocent for the structure of farming than the low prices of smartphones and tablets suggest.

Conclusions
The use of ICT will increase strongly in agriculture in the next decade. This will mean that the agrifood chain will become much more data-driven and based on up-to-date ICT. A move away from a situation characterised by a low level of data integration will have major implications for the agricultural sector. In particular, it will help solve the mismatch between current applications of ICT and the increasing need for intelligent solutions. Such a development has the potential to have a significant positive impact on issues like sustainability, food safety, resource efficiency and waste reduction.

To increase the integration of data and interoperability, we argue that investments are needed in common pool infrastructure like Agri-Business Collaboration and Data Exchange Facilities (ABCDEFs) and highlights FSpace as an example. Our conceptual analysis suggests that these will lead to a market for such facilities as well as a market for apps and perhaps even for data. This could be preferable (especially for family farms) to situations where farmers are linked to a propriety ERP system of a big input supplier or food business. Overall, however, the trend to big data may have significant consequences for how farms and food chains are organised.

Until now the development of the future internet has been dominated by research activities to design software and re-engineer business processes based on business modelling and value chain analysis. However, the economic impacts and the longer-term effects on farm structures and rural areas of the future internet require more attention. Our preliminary analysis suggests that it is not necessarily positive for the family farm, but that open systems with low switch costs are better than propriety systems where the farmer becomes a franchise taker of big firms in the chain, tied to their software system.

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