The Commercial Significance of Big Data's Application in Smart Farming

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Abstract. Big Data has been a widely discussed topic over the past few decades, and the trend of increasingly applying it prevails in multiple industries -- agriculture has been one of them. This article investigates the state-of-art application of Big Data along the agricultural supply chain by dividing it into five sections: primary production, food processing, retailing, customer, and logistics and distribution. Furthermore, this article examines the change brought by Big Data in altering the entire business model of food products by eliminating intermediaries; most typically, creating the type of B2B/B2C e-commerce supply chain. The negative and positive implications of this change are also discussed.

Keywords: Big Data, Application, Smart farming, commercial impact, business model

1 Introduction

Big data, although as a relatively new concept, has attracted large amounts of attention over the past few decades. Being founded and popularized by John Mashey [1], this concept's 3 characteristics -- "volume", "velocity" and "variety" [2] -- render it potential to satisfy the enormous needs of extracting value from the tsunami of information in our current digital age [3]. Thus, expansion in its application has become an unstoppable trend in the increasingly digitalized world.

In the meantime, innovation made in agricultural industries in the recent years ---- marked by the development of Internet of Things (IoT), a system of interconnected devices that are either linked to a network or to each other and are capable of exchanging data without the need of human - to - machine interaction, advancements in cloud computing technologies and breakthroughs in artificial intelligence ---- has facilitated the evolution of smart farming. In 2023, the global smart farming market size reached USD 16.3 billion, and is projected to rise with a CAGR of 12.86% to reach 42.92 billion by 2031 [4]. Arising based on precision farming that only accounts for inter-and intra-field variability in crops [5], smart agriculture takes a step further towards basing agricultural production decisions not only on location but also on data [6], thus making it closely tied with the concept of Big Data Analytics. Therefore, this

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study aims to investigate the mechanism by which Big Data application affects the smart agriculture supply chain and the resulting change in business model.

2 Literature Review

The benefits brought by Big Data applications in general is widely recognized, in the management of customers, information, innovation, technology and supply chains [7][8][9]. However, it has some more profound connections and impacts specifically directing toward the agricultural supply chain. Smart agriculture is characterized by the incorporation of a range of agriculture 4.0 technologies, including sensors, IoT and robotics, into farming practices [10]. Thus, it involves enormous and continuous stream of data being generated in different types, fitting into the scope of the "3Vs" and is essentially encompassed by the idea of big data [6].

Different stimuli have been identified that accounts for the popularization of Big Data applications: business drivers and public drivers that belong to pull factors, and general technological development as the main push factor [6]. For pull factors, business drivers include the needs to increase profitability and efficiency through improving management control with information generated in its local-specific context; public drivers address the rising standards of food and nutrition safety, and sustainability of agricultural practices [11][12][6]. As for push factors, lowered cost and popularization of technologies in general, including the IoT and real-time monitoring, play a vital role in making the application the Big Data possible.

Several methods have been used to describe and outline the current Big Data's applications in smart farming. The process can be summarized as a sequence of 7 stages along the data value chain, emphasizing the technical methods of capturing and processing data, as shown by Fig.1 [13][14]. For example, in the first stage -- data capture -- sensors and robotics such as Unmanned Aerial Vehicles (UAVs) are used to capture data; in the data storage stage, there are cloud-based platforms, Hadoop Distributed File System (HDFS), hybrid storage systems, and cloud-based data warehouse to store the data uploaded from the sensors [15][16].

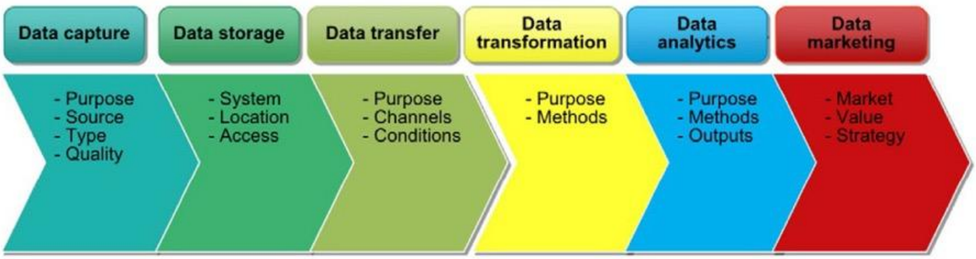

Fig. 1. The data chain of Big Data applications [6][13].

Apart from sorting Big Data applications by their locations in the data chain, they can also be outlined in terms of the stages of the cycle of smart farming, which includes four components: smart sensing and monitoring, smart analysis and planning, smart control, and big data in the cloud [6]. This way of presentation outlined how Big Data is applied in performing each specific agricultural practice. Additionally, Wolfert et al. summarized the applications in different types of farming, as illustrated by Fig. 2[6].

Cycle of Smart Farming	Arable	Livestock	Horticulture	Fishery
Smart sensing and monitoring	Robotics and sensors (Faulkner and Cebul, 2014)	Biometric sensing, GPS tracking (Sonka, 2014)	Robotics and sensors (temperature, humidity, CO_2, etc.), greenhouse computers (Sun et al., 2013a)	Automated Identification Systems (AIS) (Natale et al., 2015)
Smart analysis and planning	Seeding, Planting, Soil typing, Crop health, yield modelling (Noyes, 2014)	Breeding, monitoring (Cole et al., 2012)	Lighting, energy management (Li and Wang, 2014)	Surveillance, monitoring (Yan et al., 2013)
Smart control	Precision farming (Sun et al., 2013b)	Milk robots (Grobart, 2012)	Climate control, Precision control (Luo et al., 2012)	Surveillance, monitoring (Yan et al., 2013)
Big Data in the cloud	Weather/climate data, Yield data, Soil types, Market information, agricultural census data (Chen et al., 2014)	Livestock movements (Faulkner and Cebul, 2014; Wamba and Wicks, 2010)	Weather/climate, market information, social media (Verdouw et al., 2013)	Market data (Yan et al., 2013) Satellite data, (European Space Agency, 2016)

Fig. 2. Existing forms of Big Data Applications in different types of smart farming process [6].

However, despite studying Big Data's applications in agriculture from different perspectives, those existing literature either focuses solely on farming section of the agricultural supply chain, or explain its application at different sections in the data value chain, which emphasizes more on the technological aspect but not from the socio – economic perspective. Therefore, this study investigating the mechanism and size of Big Data application's influence on the agricultural supply chain will act as a useful supplement to existing understanding towards the current role played by Big Data in smart agriculture.

3 Big Data Application Along the Agricultural Supply Chain

3.1 Overview

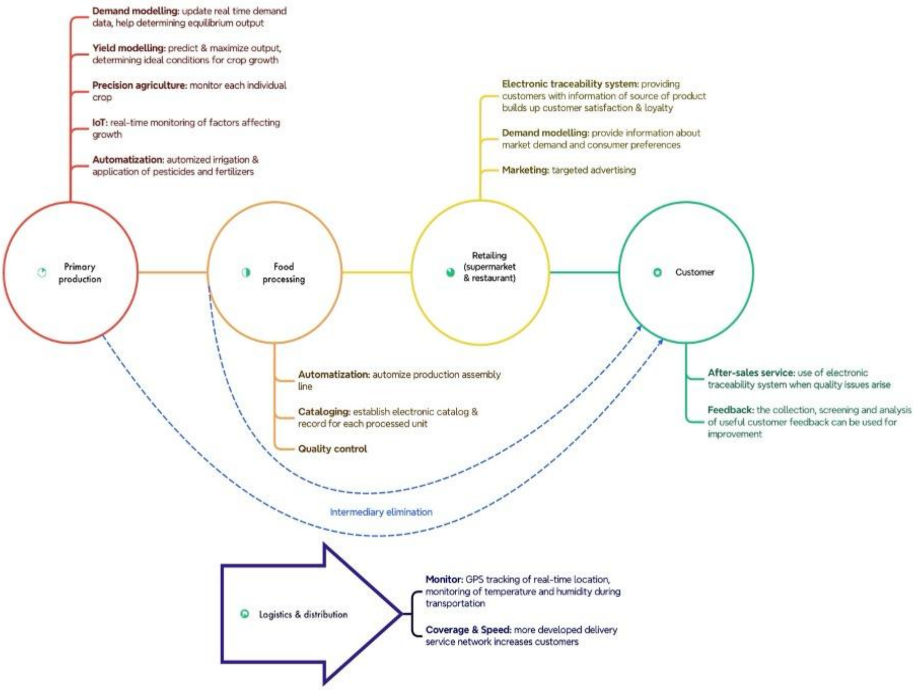

Fig. 3. Organizational flowchart of Big Data's application along the agricultural supply chain

Big Data's technologies are applied diversely and continuously along the supply chain. The chain has been divided into 4 major sections: primary production, food processing, retailing and customer, as well as the 5th component of logistics and distribution service that connects different components throughout the entire chain. Specific Big Data's applications under each component will be discussed in detail(fig.3).

3.2 Primary Production and Processing

In arable farming, this process begins even earlier than the actual plantation taking place. Through collecting demand information -- both up-to-date and future modelling

-- from the retailing and customer end of the supply chain and feeding the data back to farmers, Big Data allows for output adjustments to be made. Although not yet widely adopted, the creation of more precise demand forecasts through improving Big Data Analytics techniques might also provide possibilities for the incorporation of new concepts such as JIT to be exercised in primary production, improving productive efficiency [17].

During actual plantation, Big Data act as an indispensable tool for precision farming. This not only increases yield by tailoring the needs of individual crops, but also allows for a more thorough quality control of products by directly spotting the specific failed crop. In IoT, Big Data is used to connect different sensors monitoring real-time temperature, humidity, sunlight and soil moisture content, together with the automatic pesticide sprayer, irrigation system, and fertilizer dispenser, with the ultimate goal of creating a fully automated feedback loop, as illustrated by Fig.4 [18][19]. This process ensures that the different conditions affecting the growth of crops will be maintained within a designed range, thus saving human efforts to supervise, analyze, and respond to the crop growth data being generated and stored in

the cloud.

Fig. 4. Automatic feedback loop of field management monitoring

In the food processing component of the supply chain, Big Data plays an essential role in managing largely automatic assembly line composed of heterogeneous-data-generating machines, which significantly improves efficiency and creates economies of scale. It also allows for the establishment of electronic catalog, which creates record for and labels every unit of processed products. This facilitates a more comprehensive monitoring and control of quality.

3.3 Retailing

When reaching the retailing section, as retailers – such as supermarkets, stores and restaurants – are in direct contact with final consumers of the agricultural products, the most valuable use of Big Data would be to provide information about customers and demand, and thus forming more effective marketing strategies. For example, targeted advertising is the most popular state-of-art marketing technique made possible by Big Data. It involves posting advertisements to a specific group of people who are being identified as “potential customers” based on their website search records and preferred contents on social media, who are of greater possibilities to be interested in the product. This is widely adapted in most mainstream social media and search engine platforms including Google, Instagram and Facebook.

Furthermore, facilitated by Big Data technologies, the establishment of electronic traceability system for food products is becoming increasingly popular in the past few years. This is a system in which the products can be traced from the field by the buyer through unique lot codes, in the form of number or number-letter combination. Product information along the whole supply chain, with precision down to its specific farm of origin and harvesting or processing date, are warehoused in the system and can be easily traceable. This is a valuable to retailers as labelling the origin of their products can help improve customer satisfaction and loyalty by making them more certain of the quality of products, and therefore less concerned about issues regarding food safety. Such application is exemplified by the EU quality scheme of granting products "geographical indication (GI)", linking the product to their geographical origin and thus enabling consumers to trust and distinguish quality products

3.4 Customer Services

The traceability system mentioned above is also extremely useful in food recall instances, which falls under the scope of after-sales service of the customer section of the supply chain. In the case of failing food products, it allows the source of failed product to be spotted quickly, and thus efficiently identifying and recalling the related product groups with similar safety concerns. The significance of this was clearly illustrated by the 2017 fipronil eggs contamination incident, which involved the removal of 77.4 million eggs from the shelves of more than 15 European countries, due to the finding of fipronil insecticide inside those eggs that made them toxic [20].

The value of Big Data application to after-sales services isn't limited to food recall. It plays a crucial role in artificial intelligence modelling used in customer support, such as responding to consumers' refund requests. In China, the world's leading country in AI customer service chatbot maturity and application, its market size for has reached ¥6.68 billion in 2022, and is projected to grow to ¥18.3 by 2027, with a CAGR of 22.1%. Furthermore, through this intermediary, consumers can provide feedback on the products more conveniently, which will be collected, screened and analyzed by producers using Big Data analysis techniques.

3.5 Logistics and Transportation

In the logistics and transportation field that runs through the supply chain and connects different components, Big Data is also vital. Using GPS tracking, both upstream suppliers and downstream retailers and consumers can monitor the real-time location of the products. Apart from locations, in some cases the in-cargo conditions also need to be monitored. For example, for dairy products that need to be refrigerated during the delivery process, temperature will need to be constantly monitored.

Big Data also allows for the construction of a more developed transportation and delivery network around the globe, with greater coverage and speed. As more previously peripheral and thus isolated regions become connected to the delivery service network, cross-regional or even international trade links of agricultural products form, which increases the range of potential customers and demand for the product produced. The greater speed of delivery also makes the application of the JIT concept mentioned previously and diversifies the product offering as it is now able to deliver perishable products over longer distances.

4 Changes In Business Model Caused by Big Data's Application

4.1 Identification

The advancements made in the logistics industry, together with the increasingly extensive utilization of online communication platforms such as social media applications, have resulted in major changes in the business model of the industry, creating shorter and more compact agricultural supply chains. This e-commerce has occurred in the form of eliminating the intermediary wholesalers and retailers by allowing the direct contact and interaction between primary producers and consumers, on either social media applications or specialized platforms for farmers to sell their products. Thus, a trend of increase in direct sales instead of through intermediary has been created.

Among different types of e-commerce, the B2C/B2B (Business to consumer/business to business) type is the most straightforward embodiment, with greatest simplicity, of the new business model. As illustrated by the diagram below(fig.5), the original sections of wholesalers and retailers are replaced by the e-commerce platform, through which farmers and manufacturers are connected directly to the consumers and restaurant industries at the other end of the chain.

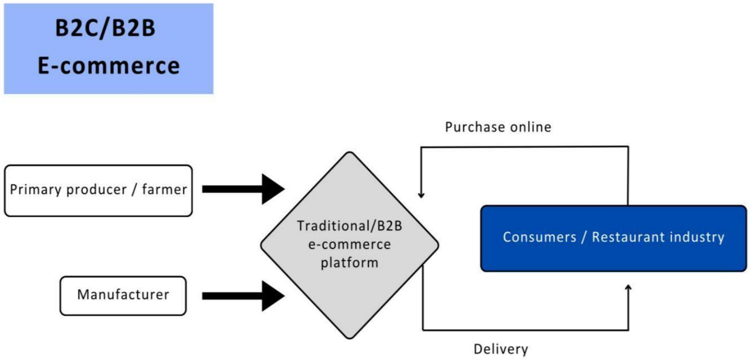

Fig. 5. B2C/B2B type e-commerce flowchart

This model has been increasingly-widely-adapted. By incorporating this type of e-commerce with marketing campaigns such as live-streaming, Chinese producers have managed to boost their sales significantly. According to the report released by Chinese TikTok, from September 2022 to September 2023, the total length of live streaming to promote sales of agricultural products reached 37.78 million hours, and 4.73 billion purchases were made through the platform.

4.2 Impacts

Advantages. The most direct advantage of the shortening of supply chain is the extended profit margin for producers. The portion of price difference charged by intermediaries as their profits is now shared between producers and consumers. Such increase in both producer and consumer surplus allows both parties to benefit from the change. Also, the simplification of selling procedure marks a great improvement in productive efficiency of the entire industry.

In addition, the closer connection and interaction between producers and their customers have fostered a new paradigm of "1+X" in agricultural marketing. In this model, "1" is the fundamental product itself, and "X" represents the different possibilities of meanings attached to the product in advertising to form a unique IP label for it. The most common combination would be to add cultural elements representative of the place of origin of the product, such as the region's own folklores and traditions. Another form of combination would be with tourism, which involves creating interactive projects such as inviting the tourist to participate in the cultivation process. The use of this paradigm helps bring a synergy effect of '1+1>2', effectively making the product to become more impressionable and identifiable, boosting its popularity.

Disadvantages. Firstly, a new sales method of online and offline hybrid is created. While the direct purchase from farmers has becoming an increasingly pervasive option, a large percentage of retailers still remains. This is partially due to the fact that the transformation to online direct sales take time, and that the availability of digital connectivity varies among different demographic groups. As intermediary sale and online e-commerce are substituting sales method, the trend of increase in direct sales may create a situation of innovative destruction: in the intermediary industries being gradually supplanted, lack of confidence towards future leads to a shrink in investment that in turn causes long term decline, accompanied by serious structural unemployment. However, at the same time, the growing prevalence of e-commerce provides opportunities for original traditional intermediaries to transform and adapt to the new platform industry, taking advantages of its rapid development.

Secondly, this change can pose risk on the stability of income for farmers. The form of cash flow of farmers adopting the new direct sale method has shifted from a one-off receivable from the upstream buyers (wholesalers) to continuous stream of smaller recipients. This is because their cash flow is now generated in real time, when consumer make a purchase of their products on the online platform. Therefore, farmers need to take the additional risk management responsibilities that were originally borne by intermediaries, whose functions include risk mitigation such as inventory management and market forecasting. Furthermore, the reliance of farmers' income on the selling platform makes them vulnerable to any technical accidents, such as the system being paralyzed, adding to the instabilities and uncertainties to farmers that arise from the shift to the new sale method.

Thirdly, certain demographic groups -- both producers and consumers -- might be excluded in participating in the newly formed supply chain. Thus, when the phenomenon of direct sales keeps expanding, or even to the extent of inhibiting or replacing the conventional method, those people may be in a disadvantaged position. The groups primarily consist of those who have limited digital connectivity and knowledge regarding the internet, due to old age or the existence of information gap, or those whose locations are beyond the reach of logistics and transportation network and thus can't be accessed.

5 Conclusions

In conclusion, as illustrated by the organizational flowchart, Big Data application affects each section of the agricultural supply chain -- including primary production, food processing, retailing, customer service, logistics -- in different ways. Such applications make every component of the supply chain more efficient, as well as constructing a more automized network at each stage and contributing to the regulation of food safety. Furthermore, Big Data application creates change in the business model of food product by directly eliminating some the sections, and thus shortens the supply chain. The implications of this change are two-sided. Despite making profit distribution more effective, improving efficiency and foster the growth of a new marketing paradigm, it also causes negative demand shock to the existing intermediary industries, adds risk to farmer's income stream, and excludes certain demographic groups.

Regarding these impacts, it is recommended that in future developments of such e-commerce applications, the stakeholders in the new supply chain should pay special attention to 3 aspects. Firstly, the e-commerce platforms should ensure that this new method indeed brings higher efficiency, instead of simply replicating the functions of traditional intermediaries. Secondly, government agencies, e-commerce platforms and producers participating in this new business model should collaborate in protecting the vulnerable demographic groups, as they are currently being excluded from e-commerce services. This can be done by expanding the logistics network or popularizing knowledge regarding online purchase among the elders. Thirdly, platforms and government agencies should explore ways to protect the income stability of farmers by developing financial products and micro-insurance, thus minimizing the disturbances brought by changed form of cash flow.

References

1. Mashey, J.R. (1998). Big Data…and the Next Wave of InfraStress. Retrieved from https://static.usenix.org/event/usenix99/invited_talks/mashey.pdf
2. Wikipedia Contributors. (2019). Big data. Wikipedia; Wikimedia Foundation. Retrieved from https://en.wikipedia.org/wiki/Big_data
3. Cavanillas, J.M & Curry, E. (2018). New Horizons for a Data-Driven Economy: A Roadmap for Usage and Exploitation of Big Data. Europe: Wolfgang Wahlster and Springer International Publishing.
4. Data Bridge Market Research. (2024). Smart Farming Market – Global Industry Trends and Forecast to 2031. Www.databridgemarketresearch.com. Retrieved from https://www.databridgemarketresearch.com/reports/global-smart-farming-market#:~:text=The%20global%20smart%20farming%20market
5. Blasch, J., van der Kroon, B., van Beukering, P., Munster, R., Fabiani, S., Nino, P., & Vanino, S. (2022). Farmer preferences for adopting precision farming technologies: a case study from Italy. European Review of Agricultural Economics, 49(1), pp. 33–81. https://doi.org/10.1093/erae/jbaa031
6. Wolfert, S., Ge, L., Verdouw, C. & Bogaardt, M.J. (2017). Big Data in Smart Farming – A review. Agricultural Systems, 153, 2017, pp. 69–80. https://doi.org/10.1016/j.agsy.2017.01.023
7. Wamba, S. F., Gunasekaran, A., Akter, S., Ren, J., Dubey,R. & Childe, S.J. (2017). Big data analytics and firm performance: effects of dynamic capabilities. Journal of Business Research, 70, pp. 356–365.
8. Grover, P. & Kar, A. K. (2017). Big data analytics: a review on theoretical contributions and tools used in literature. Global Journal of Flexible Systems Management, 18, pp. 203–229.
9. Batistič, S. & Der Laken, P. (2019). History, Evolution and Future of Big Data and Analytics: A Bibliometric Analysis of Its Relationship to Performance in Organizations. British Journal of Management, 30(2), pp.229–251. https://doi.org/10.1111/1467-8551.12340.
10. Javaid, M., Haleem, A., Singh, R. P., & Suman, R. (2022). Enhancing smart farming through the applications of Agriculture 4.0 technologies. International Journal of Intelligent Networks, 3, pp. 150–164. https://doi.org/10.1016/j.ijin.2022.09.004

11. Poppe, K.J., Verdouw, C.N., Renwick, A. (2015). A European perspective on the economics of Big Data. Farm Policy Journal 12, pp. 11-19.
12. Lesser, A. (2014). Big Data and Big Agriculture. Gigaom Research, pp.11.
13. Chen,M., Mao, S. & Liu, Y. (2014). Big Data: a survey. Mobile Netw Appl 19, pp. 171-209.
14. Miller, H.G. & Mork, P. (2013). From data to decisions: a value chain for Big Data. IT Professional 15, pp. 57-59.
15. Faulkner, A. & Cebul, K. (2014). Agriculture Gets Smart: The Rise of Data and Robotics. Cleantech Agriculture Report. Cleantech Group.
16. Zong, Z.L., Fares, R., Romoser, B. & Wood, J. (2014). FastStor: improving the performance of a large scale hybrid storage system via caching and prefetching. Clust. Comput. 17, pp. 593-604.
17. Phogat, S. (2013). Introduction to JIT: a review. International Journal of Latest Research in Science and Technology. https://www.researchgate.net/profile/Sandeep-Phogat/publication/323847797_INTRODUCTION_TO_JIT_A_REVIEW/links/5ba7b4b9a6fdccd3cb6d4eae/INTRODUCTION-TO-JIT-A-REVIEW.pdf?origin=publication_detail&_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InByb2ZpbGUiLCJwYWdlIjoicHVibGljYXRpb25Eb3dubG9hZCIsInByZXZpb3VzUGFnZSI6InB1YmxpY2F0aW9uIn19
18. Cherlinka, V. (2022). Soil Moisture: Methods Of Measuring & Tools For Monitoring. Eos.com. https://eos.com/blog/soil-moisture/
19. Hajjaji, Y., Boulila, W., Farah, I.R., Romdhani, I. & Hussain, A. (2021). Big data and IoT-based applications in smart environments: a systematic review. https://www.sciencedirect.com/science/article/pii/S1574013720304184
20. Nayak, R., Manning, L., & Waterson, P. (2022). Exploration of the fipronil in egg contamination incident in the Netherlands using the Functional Resonance Analysis Method. Food Control, 133, 108605. https://doi.org/10.1016/j.foodcont.2021.108605