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Longer Term Impacts of the COVID-19 Pandemic on European Agriculture

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Abstract

The longer-term impacts of the COVID-19 pandemic on the European food supply chain may be substantially different than the short-term adaptation of farmers, food processors and retailers. The main consumer preference changes are likely to be linked to greater on-line ordering, home delivery and in-home consumption. The food industry changes will probably be more persistent and of greater magnitude than those on the consumer side, including a preference for production and processing closer to consumption, and greater flexibility in processing. The COVID-19 pandemic will promote greater automation throughout the food chain with automation of combinable crops leading the way because the engineering is more tractable than for fruits and vegetables. The COVID-19 pandemic will lead to a re-emphasis on food production and food security in agricultural policy throughout Europe. That re-emphasis of food security will be strongest in those countries which saw the largest and longest disruption in consumer level food availability. The COVID-19 pandemic has disrupted the European food system, but in the longer run it could also create opportunities for those ready to adapt to the changing realities.

Keywords

COVID-19, food system, globalization, robotics, vertical farming, food security

Presenters profile

Prof. Lowenberg-DeBoer holds the Elizabeth Creak Chair in Agri-Tech Applied Economics at Harper Adams University. He is president of the International Society of Precision Agriculture (ISPA) and co-editor of the journal Precision Agriculture. His research focuses on the economics of agricultural technology, especially precision agriculture and agricultural robotics. He has published 85 articles in refereed journals, two books and six chapters in other books. From 1985 to 2017, he was a professor in the Department of Agricultural Economics, Purdue University, West Lafayette, IN, USA. His research is informed by experience producing maize and soybeans in the US state of Iowa.

Introduction

The COVID-19 pandemic has been a severe short-term shock to the European food system, but the longer-term effects of the pandemic are unclear. Some think that the economy in general, and the food sector in particular, will bounce back quickly to pre-pandemic conditions when restrictions are lifted. Others envision a radically different food future in which resilience is emphasised and local food production favoured. In spite of the lack of information on longer-term trends, decisions are being made now on farm policy, food safety regulation, infrastructure and other issues that will strongly influence the future food security and the profitability of the food system. To facilitate decision making in this context of uncertainty, this article outlines the key questions about the longer-term impact of the COVID-19 pandemic on the European food system, poses some hypotheses and discusses methodologies that might be used to test those hypotheses. This article is of interest to economists, food scientists, policy makers, food industry managers, farmers and consumers.

This discussion is built on the awareness that pandemics can change agriculture and society dramatically. For example, historians have found that the Bubonic plague killed so many workers in the Middle Ages that wages rose, farmers shifted from grain production which was labour intensive in those days to sheep which required much less labour, and over the longer term the feudal system was undermined laying the basis for the Renaissance and modern agricultural systems (Herlihy, 1997). The 1918 Flu Pandemic shows that the geography and demography of the disease can have a key influence on the longer-term impact. Unlike COVID-19 which kills mainly older and more vulnerable people, the 1918 flu predominantly killed working age adults, but the short-term and longer-term impact on agriculture appears to have been minimal (Garrett, 2008; Jordà et al., 2020; Patterson and Pyle, 1991). This was because the 1918 Flu was concentrated in cities and other high-density areas like military bases, leaving many rural areas less affected.

To respond to these longer-term issues Harper Adams University (HAU) staff working from their homes have searched the research literature, met on-line, exchanged emails and social media messages, and spoken on the phone. This document summarizes the key questions identified, hypotheses posed and the methodologies discussed. The HAU exchange was organized around answering some key questions, including:

Will the COVID-19 pandemic permanently change consumer preferences?

All around Europe consumers changed food practices during the COVID-19 pandemic, but the degree of change varied widely. In March of 2020, restaurants and food service were abruptly shut down in much of Europe as governments imposed “lockdowns” with varying degrees of severity. Sweden was among those imposing relatively light restrictions, mainly limited to requiring bars and restaurants to follow social distancing rules and restricting the size of public gatherings to no more than 50 people. In contrast countries like the United Kingdom, Germany, Greece, Spain and Italy closed all bars, restaurants and other eat-in food establishments and prohibited public gatherings. This forced consumers to eat at home and increased the demand at supermarkets. In most countries on-line or phone ordering and pick-up or home delivery was allowed, but it took time for many coffee shops, restaurants and other food service establishments to adapt. In the UK in particular, consumers reacted to the lockdown by panic buying of all kinds of food for home preparation, but especially non-perishable items. For many UK consumers this was the first time that they had seen empty supermarket shelves.

Human beings tend to have short memories and soon consumer behaviour will probably go back to being driven by price, convenience and habit regardless of the COVID-19 pandemic experience. Most European consumers are unlikely to willingly pay more for food because it is produced in Europe, even if that supply is more reliable. However, the pandemic may have changed some habits. Some consumers have tried on-line ordering and home delivery for the first time, and they may continue because they like the convenience. This is particularly true of older consumers who were not ordering food on-line before the pandemic.

While it would be possible to create a wholesome, nutritious diet entirely from foods grown in Europe, consumers will probably maintain their taste for citrus fruits, bananas, pineapple and other food products from warmer climates and continue demanding out-of-season produce. In response companies may diversify their supplies, and instead of relying on products from one country, they may decide to source from several.

The pandemic has revealed the fragility of long-distance supply chains. Will that realization lead to the end of globalisation?

Company changes due to the pandemic may be greater than those likely to be seen among consumers. If a company experienced major financial losses due to supply chain disruptions, resilience will become a higher priority in planning. The cost and probability of a disruption may be added into the estimates of expected profits when deciding on future strategy.

Strategies to increase resilience lie within sourcing materials, processing, logistics and marketing flexibility. Specialized supply chains focused on a single type of buyer reduces costs, but it also makes them vulnerable to disruption if those buyers dramatically change their orders. This is what led to the milk dumping and ploughing under vegetables when processors focused on products for restaurants and institutions could not quickly switch to serving the individual consumer market via supermarkets and home delivery during the lockdown. Will food supply companies post COVID-19 build in the flexibility to serve alternative marketing and distribution channels?

To reduce costs, most larger European food companies have developed a so-called "lean supply chains" with just-in-time deliveries. For less perishable foods one of the options is holding greater inventories. But who would hold those inventories? The narrow margins in the food sector make it unlikely that the supermarket chains would hold those inventories without some tax or other public policy incentive.

The current pandemic presents food supply chains with a very real need to re-evaluate their business models to face the challenges presented by conditions of social distancing and lockdown. The most affected sectors are those of foodservice and events and their supply chains. Yet, the impact on the agribusiness and food supply industries is more far reaching and has, and will continue to have, a greater impact on structure of food marketing and distribution channels in the future years; arguably more so than any other pandemic to date.

The crux of the issue relates to the current market structures and the variant levels of market concentration throughout supply chains. An evaluation of market structures suggests that across Europe around 87% of food consumed in the home is purchased from supermarkets, who collectively manage the 100 buying desks which procure the items for sale. With some 286,000 food and drink manufacturers, 250,000 wholesalers and distributors, and 12.2 million farmers, retailers play a central role in the distribution of products and wealth throughout the food supply chain. Their hold over the commercial positions in many parts of the supply chain and the delivery systems to consumers has encouraged the development of a few alternative pathways to market.

The emergence of alternative food networks, involving farmers markets, farm shops and smaller food manufacturing and distributing companies in industrialized countries has been heralded as a means of promoting economic resilience and facilitating an increase in demand for the localisation of sources of food and shorter supply chains. Consumers' need to reconnect time and place, and expressed concerns over climate change and the environmental impact of food production has opened the door to community supported agriculture (CSA), box schemes, farmers markets, farm shops, pick-your-own farms and food festivals. CSAs and box schemes report being overwhelmed with orders after the COVID-19 lockdowns started. This is their opportunity to convince new customers that the convenience and quality offered are value for money.

Therefore, farmers and processors supplying into foodservice through box schemes and direct delivery have responded in a flexible manner, and converted to home delivery, thus assisting in meeting the current shortfall in online delivery. Mainstream retailers have been unable to meet the rising domestic demand, yet the question remains as to whether the apparent immediate inflexibility of the food supply chain to unprecedented changes in demand becomes an event that results in the more permanent reconfiguration of food marketing and distribution channels.

With the right technology and policy are there products that European farmers could produce cost-effectively and reduce the likelihood of disruption? For instance, could highly automated "in-door agriculture" or "indoor vertical farming" produce some of the tomatoes, peppers and fresh winter vegetables? Indoor vertical farming is crop farming in vertically stacked layers or columns practiced in an indoor environment with LED lights.

Three common indoor growing systems are hydroponic, aeroponic and aquaponic. Studies of economics of vertical farming largely rely on simulation or cash flow analysis of secondary data for costs and prices (Banerjee and Adenaeuer 2014; Liaros et al 2016; Shao et al 2016; Avgoustaki and Xydis 2020). The number of layers in these studies vary from 2 layers to 37 floors. Crops considered include basil, spinach, lettuce, cabbage, pea, strawberry, pepper, potatoes, radish, carrots and tomatoes. Some studies included fish at the lowest level.

All studies show that the main barriers for setting up indoor vertical farming are the start-up costs, lighting costs and human costs. With the innovations in more efficient lighting and robotics in the full process of vertical farming production, packing and delivery, it is believed that the cost of production for indoor farming will be reduced substantially and fully automated robotic indoor farming will increase substantially over the next five years. This can leave the outdoor farming to cultivation of crops more suitable for large machinery (grains, non-soft fruits and vegetables such as carrots, potatoes and cabbage).

How will farm work in Europe be done in the future?

The pandemic has revealed the flaws in a fruit and vegetable production strategy that depends on seasonal foreign labour. Some firms have been able to hire domestic workers for the 2020 season, but this is unlikely to be a long-term solution. Some newly unemployed workers might be willing to do farm work as a way to earn some money and get out of the house during the pandemic lockdown, but they probably will not change their long-term career plans.

If there were practical, reliable robots to grow and harvest fruits and vegetables today, many producers would probably order them immediately. But the development of horticultural automation is in its "early days". For example, several universities have worked on robotic strawberry harvesting, but engineers say that creating a robot that can recognize a ripe strawberry and pick it without crushing it is still some years in the future. Robotics for grain and other broadacre crops has fewer technical barriers. The Hands Free Hectare project has shown that grain crops can be completely automated and at a lower cost than many expected (Lowenberg-DeBoer et al., 2019). But the farm labour shortage is mostly in horticulture, not in broadacre crops.

What are the public policy challenges raised by the pandemic impacts on food security and the viability of the European food supply?

The focus of recent agricultural policy debate in most European countries and at the European Union (EU) level has been on environmental management. Political parties competed with plans of how many trees they would plant, with almost no mention of the crops and grazing livestock displaced. The pandemic has highlighted the fragility of the European food system and the number of food insecure European citizens. One of the key public policy challenges of the post-pandemic period will be to better balance food security and environmental management concerns.

The departure of Britain from the EU is a mixed blessing in the context of post-pandemic planning for the food system. In many ways BREXIT complicates the post-pandemic agriculture and food supply challenges. The pandemic has highlighted the benefits when countries cooperate. It has also revealed the limits of such cooperation and co-dependence, even where there are long standing relationships as within the EU. In an unexpected way, BREXIT may facilitate the UK adaptation post-pandemic because it provides greater flexibility in deciding on the path forward.

One of the key food system public policy issues will be support for robotics, automation and agri-tech in general. If Europe waits for the technology to be developed elsewhere it probably will not fit the specific needs of the European agricultural sector and European entrepreneurs would miss out on the business opportunity. For public funding of research and development to be effective in making the food system more resilient it must from the beginning involve the whole technology chain from researchers, to product developers, manufacturers and farmers. Research suggests that both technology design and the regulatory framework will determine the impact of robots and automation on the food system. Food supply chain robotics could result in larger firms and greater concentration, or it could create new opportunities for small and medium scale farms.

Hypotheses:

1. Consumer food preference changes linked to the COVID-19 pandemic are primarily due to more on-line ordering of both supermarket and prepared food, home delivery and in-home consumption.
2. Food supply chain impacts of the COVID-19 pandemic are of greater magnitude and more persistent than those on consumer preferences, including a preference for production closer to consumption centres and greater flexibility in processing.
3. Automation will increase throughout the food supply chain with co-robotics (human robotic cooperation) everywhere and automation of combinable crops leading the way because the engineering problems are tractable.

4. The COVID-19 pandemic will lead to a re-emphasis on food production and food security in agricultural policy throughout Europe.

Methods

The methodological challenge is an ex-ante test of the hypotheses. Ex-post the hypotheses could be easily tested with econometric studies, but it will require a decade or more before the data needed for such an analysis becomes available. The length of time series can vary, but generally at least 20 observations are needed, and many models require at least 50 observations for accurate estimation. By that time, business will have made their marketing, infrastructure and other investment decisions. An early test of the changes in consumer preferences may come out of consumer surveys in the months after a COVID-19 vaccine or a treatment for the disease becomes widely available in Europe. This may require using a shorter time series with panel data or cross-section data in each time period. Cross-section data are collected at the same point of time for several individuals or countries. Some evidence regarding supply chain flexibility, shortening supply chains and automation might be provided by cost estimates. If those changes substantially reduce costs they are likely to be adopted. If they substantially increase costs, they are unlikely to be adopted regardless of consumer sentiment or political attitudes preferring local production. Initial evidence might be provided by engineering economic cost estimates based on technical specifications. More accurate cost estimates would be provided by data from on-going agricultural and food supply firms. Optimization models might be used to identify the least cost technology and supply chain combinations. Public policy is obviously a political decision, but “alternatives and consequences” analysis might provide insight on the costs and benefits of alternative environmental management and food security policies. Those alternatives and consequences analyses might use simulation, input/output or optimization models.

Conclusions

COVID-19 has shown again that in times of great uncertainty, data, analysis and expertise count in making decisions. That is true in public health and it is also true for decisions about agriculture and the food system. Now is the time to begin counting the cost of food supply disruptions and collecting data on how consumer preferences have changed. It is the time for researchers, agri-business and farmers to work together to understand how food supply chains can be shorter and more resilient. What technologies are needed to cost-effectively produce the foods that European consumers want? What food products could be produced closer to home? For which products does holding larger inventories make sense? For which products does diversification of sources hold the greatest promise? How can public policy balance the needs of food security and the environment? The COVID-19 pandemic has disrupted the European food system, but in the longer run it could also create opportunities for those ready to adapt to the changing realities.

Further Reading:

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Keynote Presentation: How digital innovations can lead to more sustainable agricultural systems

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Extended Abstract

Our food system, including agriculture, faces major challenges. Food insecurity and malnutrition remain an increasing challenge globally (Tilman, et al. 2011). At the same time, the agricultural production potential is under strong pressure. Climate change strongly impacts agriculture (Wheeler and von Braun, 2013, Webber et al., 2018) and soil degradation is an increasing problem (e.g. Borelli et al., 2020, Wüpper et al. 2020). Moreover, other sectors compete for land and further resources on which farming depends. This is also driven by an increasing demand for other ecosystem services produced with these resources. For example, this comprises other provisioning services such as bioenergy, but also regulating services such as climate regulations and cultural services. Finally, agricultural and food systems massively impact on the environment, ranging from contributions to greenhouse gas emissions (e.g. Chaudary et al., 2018), loss of biodiversity (e.g. Pe'er et al., 2014), to resource overuse and environmental pollution (e.g. Möhring et al. 2020). Agricultural and food systems operate beyond planetary boundaries. Sustainable solutions 'for a cultivated planet' are needed urgently (Foley et al., 2011).

Entry points to develop more sustainable agricultural systems are to increase efficiency, substitution and the re-design of current systems (e.g. Pretty et al. 2018). This is where digital innovations come into the picture. They can be vital to rendering agricultural systems sustainable (e.g. Walter et al., 2017). Digitalization can contribute to lower environmental footprints, lower costs, higher profits of farming, greater animal welfare, and to better agricultural policy (e.g. Walter et al., 2017, Finger et al., 2019, Weersink et al 2018). Yet, technology alone is insufficient. The new technologies need to be considered in conjunction with the diversity of agricultural systems (e.g. crop and livestock systems) and the markets and policies in which agriculture is embedded. Only then sustainable (and 'smart') futures of farming in the digital era can be achieved (Walter et al., 2017).

As a major component of agricultural innovations, precision farming plays an essential role in untapping potential benefits. Thus, precision farming is a key component of attempts to make agriculture more sustainable. It enables agricultural management decisions to be tailored spatially and temporally. Large farms are enables to tailor management as small farms do (Finger et al., 2019). For example, farmers can treat a field as a heterogeneous entity. This can result in more targeted use of inputs that reduces waste, cutting both private variable costs and the environmental costs. Moreover, precision livestock farming can contribute to reach economic, environmental and animal welfare goals (Berckmans, 2014). However, currently, adoption of precision farming technology is largely restricted to large farms in developed countries (e.g. Griffin et al., 2018, Finger et al., 2019). In European agriculture the uptake of precision farming is heterogeneous, but low overall (e.g. Barnes et al. 2019, Groher et al., 2020). In general, more complex precision farming technologies are adopted less. However,

potential (environmental) benefits could justify greater public and private sector incentives to encourage adoption (Finger et al. 2019).

The new Farm to Fork Strategy (e.g. Duncan et al. 2020) of the European Union responds to an urgent need to reduce environmental footprint but maintaining food production in European agriculture. Incentives, infrastructure and legal framework can expand access to precision farming (e.g. Finger et al., 2017, 2019). Digital farming technology needs to be embedded in a bigger policy picture.

Technological developments and big data advances continue to make precision farming tools more connected, more accurate, more efficient, and more widely applicable. A critical question is whether technological advances, e.g. better capacities for sensing, alone will be the game-changer. A fundamental question is whether they pay off for a wide range of farmers. For example, Drones provide high resolution data and can substantially improve decision making within the field (Walter et al., 2017). Recent evidence shows, however, that the value added in terms of saved fertilizer inputs is too small to justify investment by individual farmers (Späti et al., 2020). In contrast, technologies with lower resolution but far lower costs such as satellites may be more valuable (Späti et al., 2020). In light of lack of profitability of investments for individual farms, other channels are needed to facilitate widespread adoption. Joint investment, machinery rings, contractors will be of increasing importance (e.g. Kutter et al., 2011). This, however, may affect efficacy and efficiency of policy measures. For example, under certain market conditions, subsidies may increase contractors' welfare and not benefit farmers (Wang et al., 2020).

However, to untap the full potential of precision farming, more than saved inputs and higher outputs are needed. More specifically, the higher sustainability performance due to use of precision farming needs to pay off for farmers. The uptake can be stimulated by targeted incentives from governments and industry (e.g. taxes, price premiums, subsidies). Targeted incentives from industry such as price premium can link precision farming practice to the output market, which enhances the sustainability of governmental subsidies. Further side-benefits that need to be untapped and can justify further support from the industry is the increase in transparency in production processes to be used along the entire value chain (e.g. by enabling traceability, but also spatial and temporally explicit records of input use). Moreover, the digitalization of agricultural sector can play massive role in making agricultural policy more effective and more efficient (e.g. OECD, 2019, Ehlers et al., 2020a, b). For example, digital administration and digitalized monitoring and control of policy measures can reduce their transaction costs as it reduces paperwork, incentives to cheat and need for on the spot controls. Improved spatial targeting with help of GIS and precision farming technology can increase public value of policy measures and save costs both for the farming sector and government, when restricting application of measures only to sites where they are effective. Benefits can be enhanced further when digitalization helps targeting outcomes and not just faint proxies of desired results of policy measures. Digital data generated on farms and up- and downstream industry as well as in the public sphere, including social media, remote sensing and precision farming technologies could be strategically used for learning and informing policy making (e.g. Schaub et al., 2020). In the longer run the role of government to directly intervene in farming may change towards a broker of such digital information on farming that is then to be judged by farming stakeholders.

Moreover, precision farming will gain importance and attractiveness if it is coherently combined with conservation practices, so that we move from precision farming alone to precision farming and precision conservation. Sustainable farming practices and conservation actions are increasingly part of farmers income, for example, due to targeted direct payments and/or compensation from industry. Precision agriculture will increasingly meet 'precision conservation' (Capmourteres et al., 2018). Precision conservation uses technology, data and algorithms to target conservation practices that maximize environmental and economic benefits. It enables us to evaluate how we can implement the best viable management and conservation practices across agricultural systems (e.g. Delgado and Berry, 2009, Berry et al. 2003). Yet, the integration of precision conservation efforts in economic and policy assessments of precision farming are lacking so far. However, this integration could ensure that supporting delivery of ecosystem services may be achieved more cost-efficiently. For example, ecologically important measures like buffer and flower strips, fallow land as well as elements to increase biodiversity (e.g. skylark plots and lapwing nesting sites) can be established at sites that both maximize ecological impacts and minimize economic (opportunity) costs, e.g. if these elements are placed at points in field where yield potential is low. In that way, a wide range of ecosystem services may be targeted at. Moreover, the intertwining of precision farming and precision conservation will increasingly allow to feedback ecological and environmental information to farmers, e.g. on the environmental implications of a specific action (e.g. fertilizer application at a specific point in time and in the field). This can change farmers' behavior without the use of command and control measures or economic incentive schemes, when the information is actionable for farms and perceived as beneficial. Thus, it can foster applicability of green nudges which can increasingly be used as policy instrument (e.g. Peth and Musshoff, 2020). This combination of precision farming and precision conservation also facilitates conservation beyond the level of individual farms that are important to realize ecological and economic benefits of spatial coordination and landscape approaches (e.g. Sayer et al. 2013, Banerjee et al., 2017).

In conclusion, digital innovations can contribute to a more sustainable agriculture and can help to address challenges in the Agricultural and Food System. In particular, precision farming has a massive potential that is under-exploited so far, especially for European agriculture. To untap this potential, the current production-oriented focus of precision farming needs to be expanded. Other benefits including better environmental performance, better agricultural policies, and more transparency need to be explored. Ultimately, moving from precision farming to precision farming & precision conservation is key for a more sustainable agriculture in the future.

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Presenters profile

Robert Finger is Professor of Agricultural Economics and Policy at the ETH Zurich (Switzerland). The research of Robert Finger and his team is at the interface of agricultural sciences and economics. Research foci are the evaluation and design of agricultural and environmental policies, the adoption and diffusion of new technologies as well as risk and risk management in agriculture. Before returning to ETH Zürich, where he received his doctorate in agricultural economics, he held positions at Wageningen University (The Netherlands) and the Rheinische Friedrich-Wilhelms-Universität of Bonn (Germany).

Development of supply curves for environmental compensation measures on farmland on the example of the Stuttgart Region in Germany

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Abstract

Impacts on nature and landscape in Germany must be compensated for in accordance with the Federal Nature Conservation Act. Farmers can participate by voluntarily applying appropriate measures on their land. We used a geodata-based model to analyse environmental compensation measures on arable land from an economic perspective on the example of the Stuttgart Region, a metropolitan area where construction activities and their compensation are huge, exemplary for many European metropolises. In order to estimate a possible realistic potential, the willingness to accept for compensation measures previously determined in a discrete choice experiment with farmers in the Stuttgart region was integrated into the model. The analysis compares the economic viability of current agricultural use with the income generated from the sale of so called ecopoints by supply curve. The results show wide variation in ecopoint potential in spatial terms. The implementation of compensation measures is not economically reasonable, depending on the legal security provided by a land register entry at a price of less than 1.00 € per ecopoint in the Stuttgart city district. In contrast, measures can be implemented economically and on a large scale in surrounding districts for less than 0.60 €, regardless of legal protection. The optimal type of compensation measure from an economic point of view depends on type and land is also important. The model and its results can provide important information for decision-makers in politics, landscape planning and nature conservation.

Keywords

Production-integrated compensation. Ecopoints, Impact mitigation regulation, Stuttgart Region

Presenters Profile

Christian Sponagel studied agricultural science at the University of Hohenheim between 2014 and 2018. He finished his study with a Master of Science degree in Agribusiness. From 2019 he is working as a research assistant and Ph.D. student.

Introduction

The German Impact Mitigation Regulation as a part of the Federal Nature Conservation Act (BNatSchG) has been established to achieve a no net loss of biodiversity and soil functions. According to Article 13 BNatSchG, unavoidable significant adverse impacts on nature and landscape are to be offset by compensatory or replacement measures. Adverse or negative impacts on nature are development of infrastructure such as railway tracks or other building projects, for example. Such compensation approaches also exist in other European countries, like Austria, Switzerland, Sweden or the Netherlands. The approaches in Austria and Switzerland are quite similar to that used in Germany (Darbi et al. 2010). In Sweden compensation measures can be ordered by the Swedish Environmental Code (Person et al. 2015). In England environmental compensation is addressed by the National Planning Policy Framework (Sullivan and Hannis 2015).

According to Article 16 BNatSchG, compensation for expected interventions can also be carried out pre-emptively in Germany. Stocking of advance compensation by means of eco-accounts, land pools or other measures is governed by state law. In Baden-Württemberg this is regulated by the Ökokonto-Verordnung (*ÖKVO*). In terms of nature conservation, an intervention with sealing means a devaluation of the existing biotope type and a downgrading of the soil function. This results in a need for compensation in the amount of the difference to the initial biotope type, which is assessed in ecopoints according to the *ÖKVO*. Frequently, agricultural areas are also used for the implementation of compensation measures, e.g. by planting woody plants, and are then no longer available for agricultural production. Other often used measures are land use changes from arable land into grassland or from agricultural land to nature conservation. Since arable land is classified as low-value in ecological terms (four ecopoints per m²) in the *ÖKVO* for nature conservation purposes, there is a correspondingly high potential for upgrading. Hence intensively used grassland has six and more extensive grasslands variations from 13 up to 21 ecopoints per m². As a result, the conversion of arable land into extensively used grassland is often implemented. However, the extent of compensation measures on agricultural land in Germany is still hardly statistically recorded (Tietz et al. 2012).

According to Article 15 (1) NatSchG Baden-Württemberg as federal state specific concretization of the BNatSchG, the relevant natural areas for the implementation of compensation measures are actually defined. The measure can be carried out either in the same or in the nearest neighbouring third order natural area. The Stuttgart Region lies on the border of two natural areas, so that an intervention within this region could in principle also be compensated for in the entire Stuttgart Region (Appendix 1 NatSchG Baden-Württemberg). Nevertheless, compensation is often required in close proximity to the intervention. Ultimately, the approval authority, usually the lower nature conservation authority, decides whether the compensation must take place close to the site of intervention or also further away, i.e. in the entire natural area (Giesberts and Reinhardt 2020b). In individual cases, however, it must be considered whether compensation at the place of intervention is sensible and possible (Michler and Möller 2011).

In contrast to the often used compensation measures mentioned above there is the production-integrated compensation (PIC). This means management or maintenance measures pursuant to Article 15 (3) BNatSchG on agricultural and forestry land with continued agricultural and forestry use. It is intended to reach a permanent enhancement of the natural balance or landscape on the land and to counteract the consumption of agricultural land. At the same time, PIC offers farmers the possibility of an active participation in the compensation process, e.g. by voluntary implementation of anticipated measures (Druckenbrod and Beckmann 2018; Czybulka et al. 2012). However, it is not always clearly definable whether a certain measure can still be called production-integrated or not, e.g. flower strips. According to Mössner (2019) both forms of land sparing and land sharing are possible for PIC, i.e. production and nature conservation side by side or on the same area. In any case, PIC relies mainly on close coordination of the measure with the farmers and its implementation in consensus with agriculture. From our point of view, flower strips can therefore also be sensibly integrated into the production process, depending on location and arrangement and will therefore be considered as PIC in this study.

With the various measures that are possible on agricultural land, a different number of ecopoints can be generated, which can then be freely traded on the market in the defined regions. However, the often used compensation measures are generally valued higher than PIC in terms of nature conservation. Common to all measures is that in current practice they are predominantly associated with permanent maintenance and corresponding care costs as well as legal protection, often in the form of a land register entry. In principle, a compensation measure is permanent, depending on the type of intervention, but the maintenance period can be limited to 25 years, for example, if the intended development status of the area is stable afterwards (Lütkes and Ewer 2018). Therefore, pure management and maintenance measures, which also include the PIC, are to be implemented for an unlimited period of time (Giesberts and Reinhardt 2020a).

It can be assumed that the permanent implementation of compensation measures in conjunction with land register protection will have a negative impact on the market value or mortgage lending value of a parcel of land (Czybulka et al. 2009). According to Mährlein and Jaborg (2015), a reduction in the market value of at least 15-20% can be assumed as a result of the protection of agricultural land in nature reserves, irrespective of the associated extensification requirements. In extreme cases, the maximum reduction in value can be 70-85%. The economic merit of a measure therefore depends on the market price for ecopoints, the opportunity costs of agricultural use and market value of the parcel of land, which can be estimated by standard land values (BRW). Since the nature conservation value of PIC is often somewhat lower than that of other measures, we assume that the entry in the land register has a high influence on the economic excellence of PIC in particular. Especially in densely populated urban areas such as Stuttgart, land consumption by settlement and transport areas is particularly high and the competition between different land uses is associated with a high potential for conflict. In addition to the loss of land due to construction activity itself, possible compensation measures also can have a land-scarring effect.

Against this background, we investigated the role of agriculture in the compensation process and the associated conflicts, but also the opportunities in the Stuttgart Region. As the acceptance of the farmers plays a decisive role in estimating a realistic compensation potential, a discrete choice experiment (DCE) with farmers was conducted before this study. From the total number of 209 participants, 65 came from five of the 6 districts of the Stuttgart Region. About 50% were part-time farmers, which is slightly below the average of about 61% in the Stuttgart Region (Statistisches Landesamt Baden-Württemberg 2017). In addition, most farmers were between 40 and 50 years old, which is quite representative for Baden-Württemberg (Statistisches Landesamt Baden-Württemberg 2017). Farmsize varied between

21 and 220 hectares with an average of about 67 hectares. Small farms were thus underrepresented ,which was also reported by similar DCEs, e.g. Schulz et al. (2014). However, the farms with more than 50 ha cultivate more than 50% of the agricultural area in the Stuttgart Region. Although the DCE is not generally representative for all farms in the Stuttgart Region, it nevertheless reflects a relatively high proportion of farms. The focus of the DCE was mainly on the legal security of the measure, i.e. the entry in the land register and the preference of the type of measure, e.g. PIC or conversion of arable land into grassland. Other attributes were the potential loss of market value, hence the BRW of the land, the care and maintenance period of the measure, the legal handling (transaction costs) and the annual amount of monetary compensation. From the DCE we derived values for the willingness to accept (WTA) that were used in this study to assess the costs of the measures more realistic, i.e. including a certain risk surcharge on the price (Petig et al. 2019). This means that the possible reduction of the market value is included in the WTA.

The excellence of various compensation measures on arable land in the Stuttgart Region (approx. 73,300 ha) were analysed with the help of a geodata-based model and a spatially differentiated estimate of the potential for nature conservation compensation measures will be made. The future need for compensation up to the year 2030 in ecopoints is derived from an estimate of the Verband Region Stuttgart. Based on the net present value, the model chooses between five possible compensation measures or the retention of the previous agricultural land use.

Our study was motivated by the following hypotheses:

H1: From an economic point of view, agriculture in metropolitan regions can provide compensation areas in consensus with compensation obligors, in principle.

H2: There are strong spatial disparities as regards the economic merit of compensation measures on agricultural land.

H3: In certain parts of the region, PIC is the only way to implement compensation measures at a normal market price for ecopoints.

H4: In the case of abandonment of the land registry safeguards, there would be a high potential for PIC throughout the region.

Methods

Description of the study area

The Stuttgart Region consists of the districts of Esslingen, Ludwigsburg, Rems-Murr-Kreis, Göppingen and the city of Stuttgart. It is characterised by a high spatial disparity of demographic, economic and natural characteristics (IREUS 2011). In the urban district of Stuttgart, crops like vegetables and fruits are cultivated on about 11% of the arable land, whereas the share in the district of Göppingen is only 0.4%. This is also where the highest proportion of permanent grassland in the utilised agricultural area (UAA) is found, at around 56%. In the city district of Stuttgart, this is markedly lower at about 29% (Figure 1). The Stuttgart region takes up about 10% of the area of Baden-Württemberg, but 16% of the land consumption in Baden-Württemberg in the years 2000 to 2016 took place there (LUBW 2018). This means that compensation measures under nature conservation law play a major role in this region.

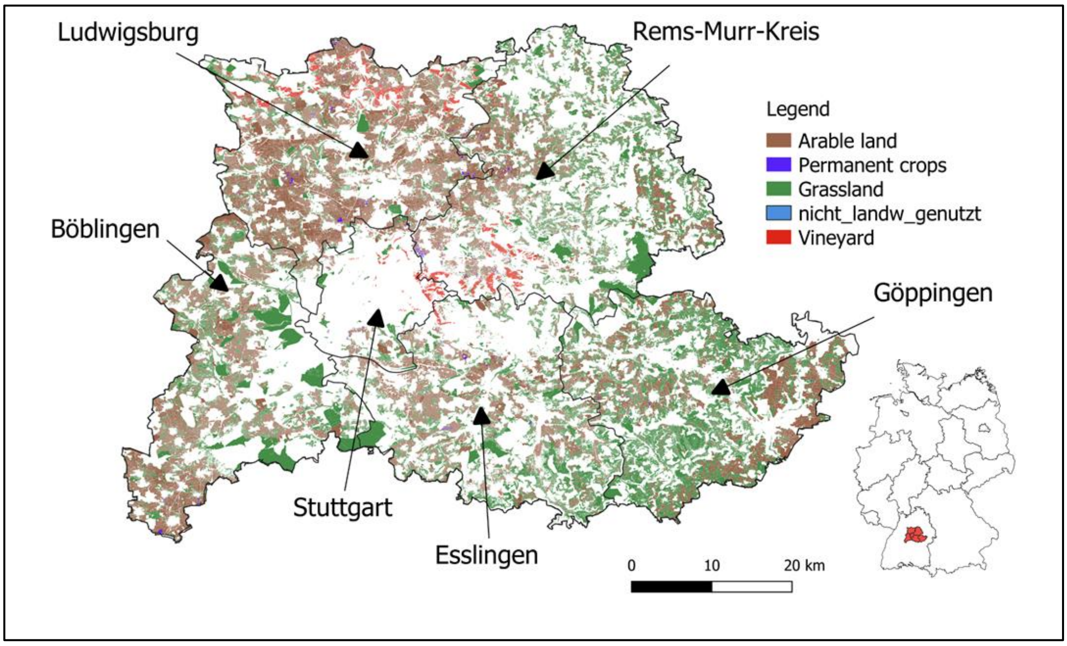

Figure 1. Overview of the agricultural land use in the districts of the Stuttgart Region (BKG 2018).

Economic evaluation of the agricultural production in the region

Based on data from the integrated administration and controlling system (InVeKoS) for the years 2015 to 2018, we derived parcel-specific crop rotations and their average contribution margins. In total, the considered arable land (ARA) consists of 72,494 ha and 265,356 parcels and corresponds to about 56 % of the agriculturally used area in the region. The remaining UAA consists of 40 % permanent grassland and 4 % orchards, vineyards and set aside areas.

The individual site conditions and thus the yield capacity are taken into account by a soil evaluation map, so called Flurbilanz (LEL 2011). The parcels are divided into three value levels standing for the yield capacity: high (priority area 1), medium (priority area 2) and low (boundary and lower boundary). For approx. 11% of the parcels there is no valuation in the Flurbilanz, therefore that these are allocated on the basis of the soil function valuation of the Verband Region Stuttgart ("value level" 4.5 to 5 high, 2.5 to 4, medium and 0-2 low). The calculation of contribution margins (in the following abbreviated CM) is based on standard calculation data and price statistics (LEL 2018a, 2018b; KTBL 2019a, 2019b, 2019c, 2010; LfL 2019; AMI 2017, 2018, 2019; AWI 2019) as well as individual publications (LFULG 2006; Statistik-BW 2018; AWI 2019). In order to estimate the refinement value of arable fodder via animal use, arable fodder plants are valued at 11.75 €/GJ or 0.23 €/10 MJ NEL, depending on their GJ or MJ NEL content, respectively, based on the price for maize silage. As a result, the forage areas are comparatively highly valued and livestock farming is relatively well covered, especially as this does not play a major role in the city of Stuttgart (Statistik-BW 2020). For areas under agri-environmental measures and ecological priority areas (ÖVF), the average CM of the main crops in the crop rotation are allocated in a simplified manner. Set-aside arable land, such as unstocked orchards, were not taken into account, as these probably offer less potential for nature conservation than intensively used arable land. All prices and costs are net amounts from a tax point of view.

The mean CM differ significantly within the region due to the different crop rotations and the yield level (cf. Flurbilanz) (Table 1). For example, the CM in Stuttgart are about four times higher than in the district of Göppingen. The CM are capitalised using the perpetual annuity formula and an interest rate of 2%.

Table 1. Descriptors and economic framework of the structure of agriculture in the Stuttgart Region.

Urban/rural district	UAA in ha	Share of arable land (ARA) [%]	Share of specialty crops on ARA [%]	Share of cereals in the crop rotation [%]	Mean BRW for arable land in €/m²	Mean contribution margin per ha [€]
Böblingen	22,344	66.7	1.3	62.3	4.71	605
Esslingen	19,555	50.3	9.2	51.6	6.52	1.563
Göppingen	27,828	43.5	0.4	49.6	3.15	519
Ludwigsburg	31,429	76.1	2.3	54.3	3.90	814
Rems-Murr-Kreis	25,430	45.6	2.9	45.4	4.47	993
Stuttgart	2,433	55.7	11.0	48.6	15.97	1,922

Standard land values (BRW) in the Stuttgart Region

For about 60% of the municipalities in the Stuttgart Region, average BRW (Table 1) differentiated according to arable and grassland are available from the respective expert committees of the municipalities, mainly from 2018. These were viewed online and serve as estimates of the market value of all parcels of land in a municipality. We calculated the missing BRW for the remaining municipalities by spatial interpolation from the mean values of the neighbouring municipalities. This is done in RStudio (R Core Team 2019) using the "idw" function from the R package "phylin". The available values of all other communities are weighted with the squared inverse distance (Tarosso et al. 2015).

Compensation measures being considered for the Stuttgart Region

For the estimation of the ecopoint potential, it is assumed that with a few exceptions, in principle, a compensation measure under nature conservation law can be implemented on each plot of land. In addition to the current agricultural use (M0), five compensation measures M1 to M5 are available per parcel (see also Table 2). In accordance with the *ÖKVO*, the measures M1 to M5 are assessed in ecopoints. Starting from the initial state M0 (arable land with four ecopoints per m²), the potential for upgrading M1 to M5 is determined. Since measures such as flower strips are not available as such in the *ÖKVO*, the resulting biotope type must be estimated in practice by the lower nature conservation authority. For the evaluation of the measures in ecopoints, the Flächenagentur Baden-Württemberg (www.flaechenagentur-bw.de), as a qualified service agency for the planning and implementation of compensation measures was involved. It has also to be considered that some measures like M4 or M5 might not lead to the aimed target condition if they are implemented on parcels with a relatively high yield capacity value and corresponding potential for natural nitrogen mineralisation (Wagner 5/7/2020). This could even have negative effects on nature conservation, e.g. the proliferation of unwanted weed species (Czybulka et al. 2012). Low nutrient levels and dry soil conditions in particular can promote the development of a species-rich flora (Gilhaus et al. 2017). While extensification of agriculture may not be appropriate in these locations, flower strips can be also successfully implemented even at highly productive sites (Czybulka et al. 2012).

The maintenance costs of the measures M1 to M5 are capitalised with an interest rate of 2%. For all measures, in order to ensure permanent maintenance, it is assumed that there is a securing land register entry, which is taken into account by the WTA values of the DCE. It is also assumed that the conditions for receiving direct payments from the first pillar of the EU CAP are equally fulfilled for all measures.

M0 corresponds to the status quo, i.e. the previous agricultural use is continued. There is no revaluation in ecopoints, there is no loss of market value and the capitalised average CM is set according to the mean contribution margin of the crop rotation (see Figure 2).

M1 corresponds to the PIC using the example of the planting of a permanent flowering strip on 30% of the area of the parcel. Compared to agricultural use, this results in an appreciation of eight ecopoints per m². The costs of a one-year flowering strip are assessed at about 31.5 € per ha (KTBL 2019a) and corresponding to a measure area of 30% of a parcel € per ha and year or capitalised at 1,576.5 €. Hence 70% of the CM of the crop rotation remains. M1 is a maintenance and management measure for an indefinite period.

M2 is the conversion of arable land into grassland with extensive use, i.e. one cut per year. For the target condition 13 ecopoints per m² are assumed. This results in an appreciation of nine ecopoints per m². The annual revenue of the grassland yield is already included in the WTA for this measure, as the farmers in the DCE did take this already into account. It is assumed that the grassland is used also for more than 25 years.

In the case of M3, with the planting of a perennial flowering on 100% of the parcel area, a complete use for nature conservation is realised. In practice, such measures are often valued at 12 ecopoints per m², i.e. an appreciation of eight ecopoints per m². The costs are set at 105.10 € per ha and year (KTBL 2019a) for the duration of 25 years, the capital value is therefore 2,052 €. In contrast to M1 we assume that the biotope created will then no longer require any maintenance.

M4 corresponds to PIC using the example of doubled seed row spacing in cereals with a waiver of the use of pesticides. This measure is carried out in rotation. This results in an appreciation of six ecopoints per m². The actual amount of the measure is based on the current share of cereals in the crop rotation on the respective parcel. Hence a share of cereals in the crop rotation of 50% would lead to an appreciation of three ecopoints per m². It is assumed that the measure will lead to a yield loss of 50% or a loss of CM of 60%. For reasons of nature conservation, this measure is limited to parcels with the yield capacity value levels medium and low. It is assumed that M4 is to be implemented as a maintenance and management measure for an indefinite period as well.

M5 is the conversion of arable land into a lean meadow. This measure is treated as a complete transfer to nature conservation as only marginal quantities and qualities of the growth can be expected. Hence the annual cutting is considered as a pure management measure. Possibly the growth can be used as litter. The appreciation is assessed with 13 ecopoints per m². The costs are set at 278 € per ha and year (KTBL 2019a) for the duration of 25 years, the capital value is therefore 5,432 €. We assume that the biotope created will then no longer require any maintenance. This measure is limited to parcels with the yield capacity value level low.

Table 2. Summary of the possible compensation measures M0-M5 in the model with description and evaluation in ecopoints.

Measure	Description	Improvement in ecopoints per m² ARA	Improvement in ecopoints per ha ARA
M0	Status Quo	0	0
M1 (PIC)	Permanent flower strips (30% of the parcel)	8	24.000
M2	Conversion to grassland	9	90.000
M3	Transfer to nature conservation	8	80.000
M4 (PIC)	Double seed row spacing	6	60.000 x CE*
M5	Lean meadow	13	130.000

*Proportion of cereals in the crop rotation per parcel

The revenue from the sale of ecopoints was calculated by multiplying the number of generated ecopoints per hectare *ÖP* by the selling price per point *p*, which is a significant factor. Thus the capital value of the measures *Mi* with *I* = 0, 1, 2, 3, 4, 5 is calculated as a whole from the proceeds of the sale of the points, reduced by the loss in market value of the parcels *VV* and the capital value of the CP (costs and proceeds) K_{CP} (Formula 1). The maintenance and management costs consist of the pure capitalized costs or revenues from the care of the measure, the WTA 1 as a risk surcharge for the care and management and the WTA 2 for the acceptance of the land register entry (Table 3).

$$\boldsymbol{capital\ value_{Mi}} = \ddot{O}\boldsymbol{P_{Mi}} \times \boldsymbol{p} \pm \boldsymbol{K_{CP\ Mi}} \tag{1}$$

Table 3. Composition of the costs of the measures including the WTA values determined in the DCE.

Measure	Capitalised costs / revenues in € per ha for care of the measure	WTA 1 in € per ha (care and management)	WTA 2 in € per ha (land register entry)
M0	CM*	0	0
M1 (PIC)	-1,576.5 + 0,7 x CM	- 7,417**** – 9,114*** - 500.1 x BRW	- 14.631,1
M2	0	- 25,633**** – 30,380*** - 1,667 x BRW	- 25,427
M3	-2.052	- 21,304**** – 30,380*** -1,667 x BRW	- 25,427
M4 (PIC)	CM – (CMC***** + 0.4xCMC)	(- 7,417**** – 22,607*** -1,667 x BRW) x CE**	- 36,803 x CE
M5	- 5,432	- 32,102**** – 30,380*** -1,667 x BRW	- 25,427

* Contribution margin of the crop rotation

** Proportion of cereals in the crop rotation per parcel

*** For a 100% loss of yield, the participants demanded a compensation of 1560 € per year. However, as the contribution margin is higher for individual parcels, the difference was added. This can be explained by the fact, that farmers did rather not consider, to implement compensation measures on these parcels.

**** Risk surcharge that farmer in general consider to implement compensation measures.

*****Capital value of the cereal production

Scenarios

In the DCE, we found that the entry in the land register has a significant effect on the acceptance of a measure. Under certain circumstances, however, the entry in the land register may be omitted. E.g. according to Article 10 (2) of the Bavarian Compensation Ordinance (BayKompV) a waiver of the entry in the land register would be possible in the case of PIC. In this case, a contract under the law of obligations between the causer of the intervention and an institution such as a recognised foundation guarantees the implementation of compensation and farmers have the opportunity to implement it on their land. Therefore, we differentiated two scenarios. In scenario 1 we assumed that the land register entry is necessary for all compensation measures M1 to M5. In scenario 2 we assumed that it is possible to waive the land register entry for M1 and M4 (both PIC).

In the model, the use of each individual plot of land is optimised from an economic point of view. For each parcel, the model selects the measure that yields the highest net present value, that is, either the status quo (M0) or one of the compensation measures M1 to M5 (Figure 2). The price is systematically increased in the interval from 0.10 € to 1.50 € per ecopoint in steps of 0.10 € and the result with spatial distribution is stored in each step.

Functionality of the model

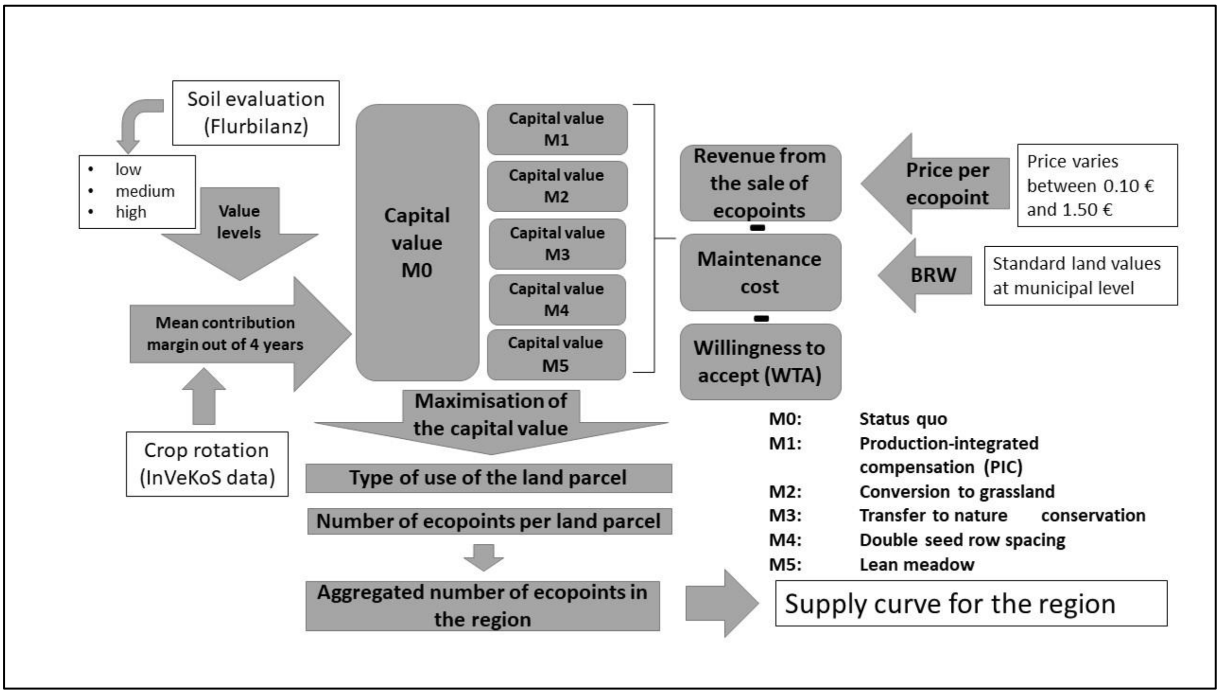

Figure 2. Overview of the structure and functionality of the model.

To represent a form of supply for ecopoints in the region, a smoothing curve is fitted to the data using the LOESS method. This corresponds to a local linear regression model (Zuur 2012). A smoothing parameter of 0.4 is used in order to fit a curve close to the data points. Hence there are three supply curves fitted, i.e. for mean capital value and capital value of M0 with change of minus or plus 20%.

Results

In scenario 1, a maximum of approximately 6 billion ecopoints can be created at a price of up to 1.50 €. From a price per ecopoint of approx. 1.00 €, however, hardly any additional points can be generated. The supply curve as a result of senario 1 is equal to a saturation curve (Figure 3). The sensitivity of the supply curve to the capital value of the crop rotation (M0) highly depends on the price per ecopoint. Up to approximately 1.00 € per ecopoint, variations of 20% of the capital value of M0 have little influence. Below a price of approximately 0.70 € no significant number of ecopoints are generated.

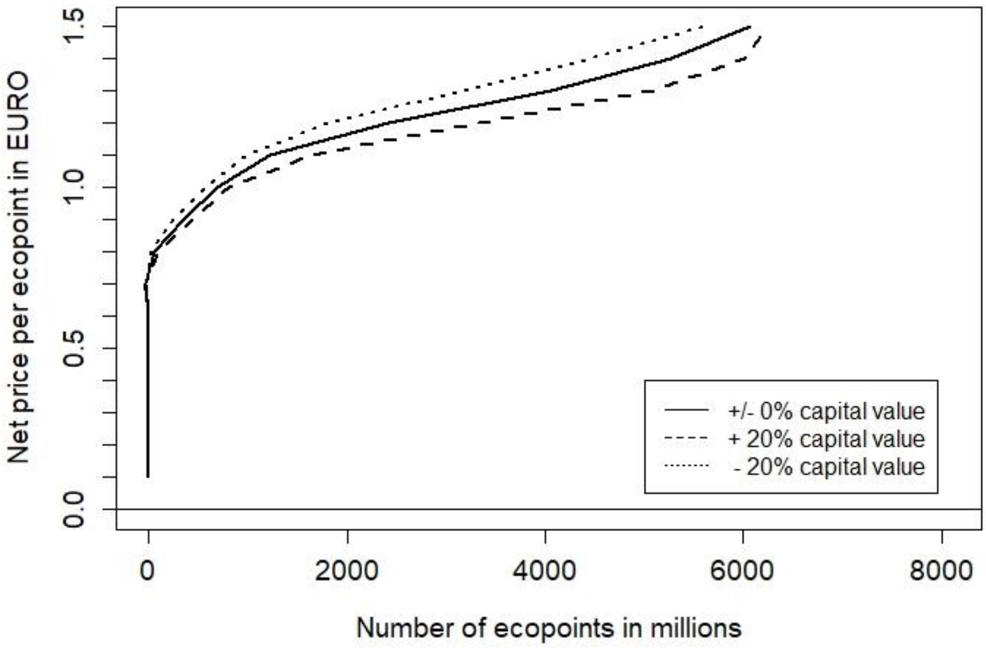

Figure 3. LOESS regression curves of the supply for ecopoints on arable land in the Stuttgart Region with mean capital value, -20% (dashed) and +20% capital value (dashed) as a function of the net price for ecopoints (scenario 1).

Up to a price of 1.30 € no PIC (M4) is implemented in the Stuttgart Region in scenario 1. However, at a price of 1.50 € per ecopoint, M4 accounts for only up to about 7% of arable land in a few municipalities and less than 1% overall in the Stuttgart Region. The measures M1 and M3 are not implanted any price included in the analysis. At a price of 1.00 € per ecopoint exclusively the measures M2 and M5 are implemented, which means a conversion of arable land into grassland. There are also regional disparities, e.g. in the district of Stuttgart no measures would be implemented at all (Figure 4).

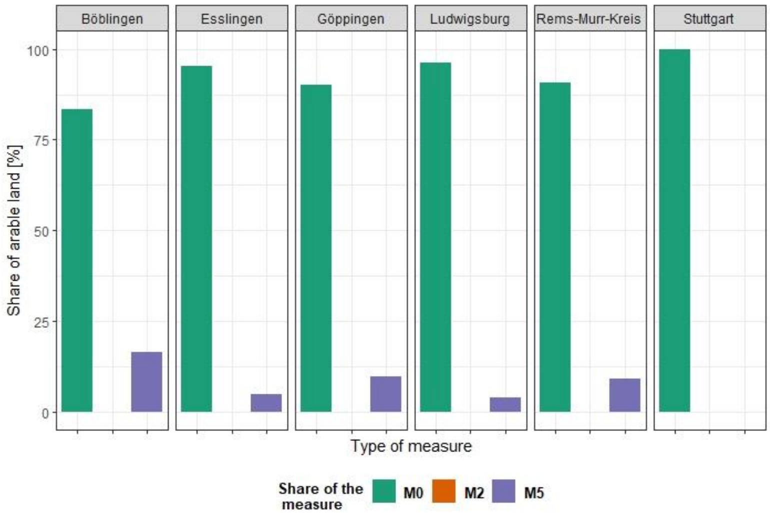

Figure 4. Overview of the type of compensation measures carried out under scenario 1 and a price of 1,00 € per ecopoint in the districts of the Stuttgart Region.

In scenario 2, up to a price of around €1.50 per ecopoint, a slightly smaller number of ecopoints are generated than in scenario 1, at just under 5.2 billion. Now a significant number of ecopoints could be be generated at a price of 0.60 € per ecopoint. Up to approximately 0.90 € per ecopoint the change of 20% of the capital value of the crop rotation seems hardly to have an impact (Figure 5).

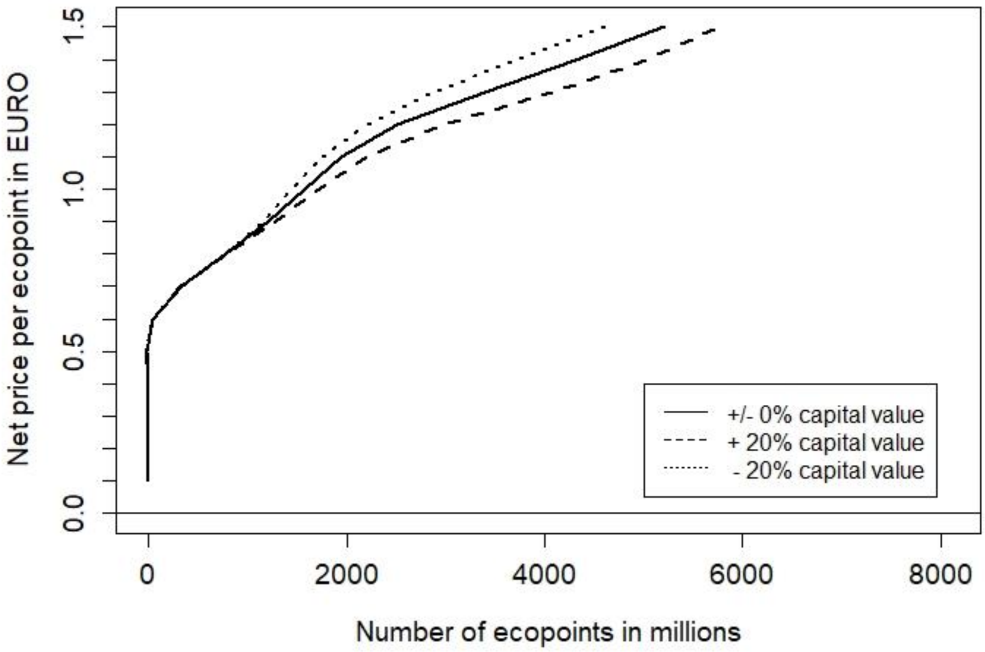

Figure 5. LOESS regression curves of the supply for ecopoints on arable land in the Stuttgart Region with mean capital value, -20% (dashed) and +20% capital value (dashed) as a function of the net price for ecopoints (scenario 2).

Up to a price of around 0.80 € per ecopoint, only measure M4 will be implemented. The share of M4 increases up to a price of about €1.00 per ecopoint to about 40% of the arable land in the Stuttgart Region and then decreases in favour of measures M1, M2 and M5 up to a price of 1.50 € per ecopoint to an average of about 25%. M1 has its highest share of arable land with just under 20% at a price of around 1.20 € per ecopoint. At a price of 1.50 € per ecopoint the maximum shares of M2 and M5 of about 53% and 10% of the arable land respectively are reached. Figure 6 shows as an example the share of M0 to M5 in the arable land at a price of 1.00 € per ecopoint by district. It is obvious that in scenario 2 the regional disparities between the individual districts with regard to the type and scope of the measures are even more evident than in scenario 1. Whereas in the district of Stuttgart only M4 is implemented with a share of approximately 2% of the arable land, in Göppingen more than 75% of the arable land would be occupied with compensation measures.

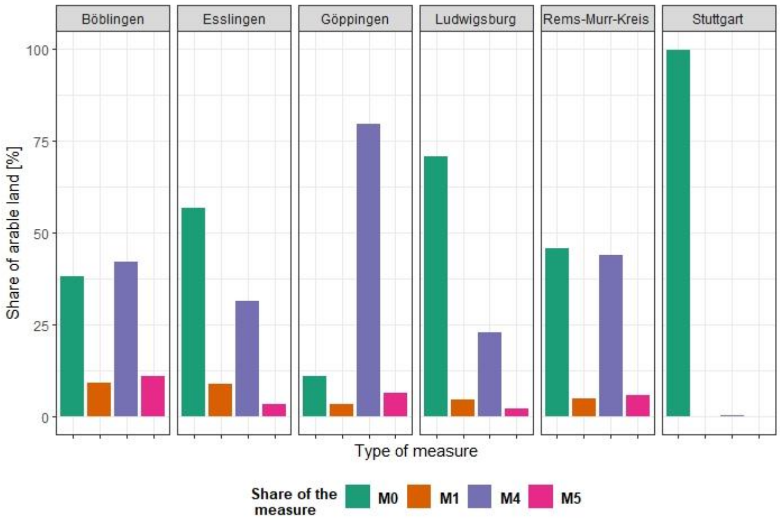

Figure 6. Overview of the type of compensation measures carried out under scenario 2 and a price of 1,00 € per ecopoint in the districts of the Stuttgart Region.

The results show that the high potential for the implementation of compensation measures on agricultural arable land in the Stuttgart Region is spatially highly differentiated (Figure 7). Implementation of compensation measures would probably be most favourable in the eastern districts of the region (e.g. Göppingen and Rems-Murr-Kreis). Higher implementation costs must be expected in the centre of the region.

Discussion

In the city district of Stuttgart and the neighbouring communities, the BRW for farmland is comparatively high at around 16 €/m², hence the potential loss in the market value of the area can be very high. In addition, proportion of highly profitable special crops is high. Therefore, a higher price per ecopoint is necessary to implement compensation measures than in the more rural communities with a greater distance to the centre of the region. Under scenario 1 no compensation measures would be implemented in Stuttgart at a price of 1,00 € per ecopoint, under scenario 2 just in a small amount. Hence, we can accept our hypothesis H2 that there are spatial disparities as regards the economic merit of compensation measures on agricultural land.

In comparison to conversion into grassland (M2 and M5) and complete transfer to nature conservation (M3), production-integrated compensation (M1 and M4) entails a relatively low nature conservation upgrading under the *ÖKVO* in relation to the costs. Especially at low BRW, the PIC is less attractive, as the higher revaluation in ecopoints in M2 and M5 overcompensates the higher loss of market value.

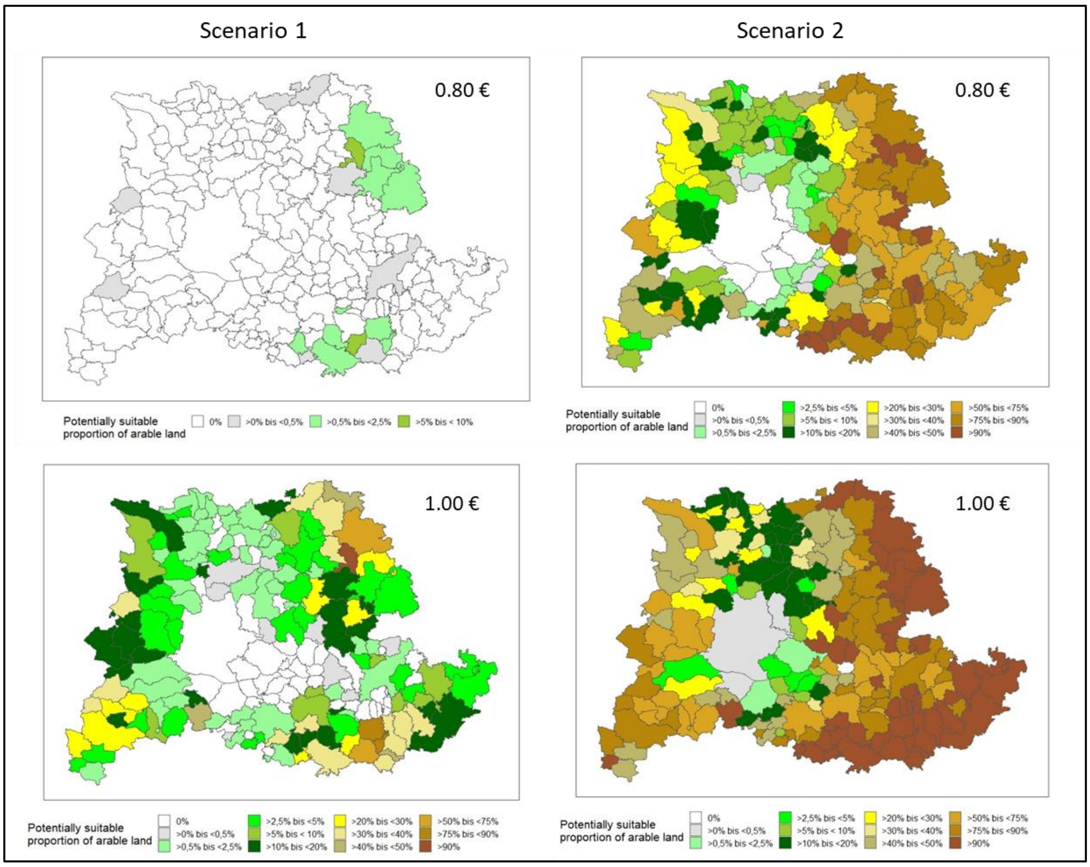

Figure 7. Overview of the spatial distribution of the compensation measures under scenario one and two and prices per ecopoint of 0.80 € and 1.00 € (BKG 2018).

In Scenario 2, where no land registry protection and no loss of market value is applied to PIC (M1), PIC is not applied to any area below a price of 0.60 € per ecopoint. However, in the urban district of Stuttgart, M4, at a price of 1.20 €, accounts for more than 10% of the arable land. Under these conditions, PIC is gaining in relative excellence, especially in the centre of the region. With regard to the peripheral areas of the region, however, the influence is small (Figure 7). The attractiveness of PIC can therefore be increased by not having to secure land registry rights and can also lead to the implementation of compensation measures close to intervention in areas with high BRW. Presumably this will increase the willingness of farmers or landowners to participate in such measures and thus enable compensation in the case of continued agricultural production.

The measures M1 and M3 do not maximise the capital value of CM on any area in Stuttgart. In general, the PIC, which is desirable from the point of view of agriculture, is in strong competition with other measures that lead to a high revaluation in ecopoints, but at the same time no longer allow agricultural use and food production, e.g. M5.

In order to be able to relate the model results to a comparatively realistic demand for ecopoints, an estimate of demand by the "Verband Region Stuttgart" can be used. This estimate, evaluates all known plans for future land development in the Stuttgart Region for the period from 2019 to 2030 and derives a demand of approximately 775 million points

(Jenssen 2020). Based on the results of our analysis, this requirement would be reached in scenario 1 at an ecopoint price of about 1.02 € (0.99 € - 1.06 €) and compensation measures would have to be implemented on about 9% of the arable land in the Stuttgart Region. If we assume that only 60% of all ecopoints are to be generated on arable land that the price will vary between 0.91 € and 0.97 €. At this price, these would mainly be located in the districts of Göppingen and Rems-Murr-Kreis. Under scenario two 775 million ecpoints could already be generated at a price of 0.80 € per ecopoint. In this case the sensitivity to the contribution margin of M0 is with less than 0.01 € not significant and about 30% of arable land would be covered by measures. However, it should be noted that mainly M4 would be implemented as a rotating PIC, i.e. not all areas would be occupied at the same time. With a share of about 50% cereals in crop rotation, this would mean that only about 15% of arable land would be used annually.

Nevertheless, the results of the DCE show that there are also farmers who have not accepted any measures at all, but in general they decided in favour of a conservation compensation measure in about 49% of the cases. On the one hand this somehow limits the interpretability of the results, but on the other hand there are increasing social demands and preferences for biodiversity and nature conservation, which are also observed by farmers (Lange et al. 2015; Fleury et al. 2015) and protection of landscape and the environment becomes part of the farmers` roles (Schmidt and Hauck 2018). Therefore, participation in nature conservation compensation measures could also become more attractive in the future.

Although PIC ultimately leads to a lower nature conservation appreciation of the area, it has a much greater overall spatial impact. According to Mössner (11/18/2019) our derived prices for meeting demand under scenarios 1 and 2 per ecopoint appear to be within a usual price range. Therefore, we can accept our hypotheses H3 and H4 that PIC is the only way to implement compensation measures in certain parts of the region at a usual market price and that there is a high potential for PIC in the whole region if the land register entry is abandoned. It should be noted, however, that the ecopoints will probably be needed successively in the period up to 2030 and that costs may change until then from today's perspective.

As the evaluation of the compensation measures may differ between the lower nature conservation authorities, this aspect also plays a role in the excellence of the measures. For example. In addition, the capital values could be calculated with interest rates different to 2%. It has also to be taken into account that compensation measures can also be carried out in forests or municipal areas which are not used for farming. Therefore, the interpretability of the supply curve is quite limited. It must also be noted that in each case the average values for the WTA were used. Therefore, there may be farmers who are willing to implement compensation measures at lower cost. The ecopoints trade would then take place mainly with these farmers. Finally, we can accept our hypothesis H1 that agriculture can still provide compensation areas in metropolitan areas from an economic point of view. Even if the supply of compensation measures might be overestimated, we show that there is a significant potential.

Our analyses can thus show political decision-makers, among others, what additional costs can be caused by compensation in close proximity to the place of intervention. The city of Stuttgart, for example, has the goal to carry out compensation measures for interventions in the city area mainly within the city limits (Koch 2009).

Outlook

There is still a need for research on the extension of our modelling approach. One aspect is the reduction of land consumption through compensation measures and thus also the consideration of food production in terms of regional supply, e.g. by analysing the resulting import requirements and environmental impacts. PIC could also play a role in this context, but it must be designed in such a way that agricultural production can continue, but at the same time a high degree of upgrading for nature conservation is possible. PIC, for example, could be implemented with species protection measures such as wildflower strips for the targeted promotion of partridges. In order to take effects on local species populations into account, further nature conservation-related technical data are required which can be integrated into the developed model. All in all, however, even PIC cannot prevent land consumption at all, since ultimately there is always a certain loss of yield. In the next step our model could also be linked with a biophysical model to include yield data for the crops with a higher spatial resolution than the three assumed intensity rates (Mitter et al. 2015).

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From sustainable development to sustainable finance

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Extended Abstract

The scientific interest and concerns in the field of sustainable development have made significant progress in recent years. We are witnessing a growing body of research which brings empirical evidence of how this paradigm has been recognized, accepted and internalized by economic agents. However, despite this progress, many studies have shown that there are still gaps in the conceptual substantiation and question whether this concept has been understood correctly. The financial market plays an important role in the transition from the paradigm of economic growth to the new paradigm of sustainable development because it allocates financial resources efficiently to the most productive investments. But, from the perspective of finance discipline, the approaches seem unsatisfactory, with unanswered questions.

Therefore, through this paper our contribution is twofold. On one hand, we draw attention to the significant gap in the existing literature regarding sustainable development issues and briefly present the developments that have emerged in the discourse on sustainable development. The generally accepted and most frequently used definition is the one formulated by the Brundtland Commission in 1987, which views the sustainable development as "…development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987). A few years after introducing this concept, Lélé (1991) identified a lack of consistency in its interpretation and significant weaknesses in its formulation pointing to an incomplete perception of poverty and environmental degradation and confusion about the role of economic growth. A decade later, Banerjee (2003) drew attention again to the weaknesses of the sustainable development approaches. He stressed that this term was introduced in order to address the environmental issues generated by economic growth, but expressed concerns about the ambiguity regarding what is sustainable (economic growth, the environment or both), showing that precisely these ambiguities are the subject of debate. Hopwood, Mellor and O'Brien (2005) also showed that all the supporters of the new paradigm agreed on the need to change society, but that they have not yet concluded and are still debating what tools are required and what actors should be involved in this process as still there is no unitary view.

Ike et *al.* (2019) support the idea that the private sector is the key factor in achieving the sustainable development goals through corporate sustainability actions, such as cleaner production, provision of decent work and economic growth, but emphasize that it is still unclear how companies can operationalize these goals through corporate sustainability. Fatemi and Fooladi (2013) believe that the source of these ambiguities and divergences can also be an academic problem. In their opinion, traditional financial theories focus on maximizing shareholder wealth, and according to the efficient markets hypothesis, today's share price is the only indicator to observe. This points towards the second contribution of this paper which is the discussion, at a theoretical level, about the transition from the traditional approach to finance to a more holistic one described by the new paradigm of

sustainable finance. Financial markets through their mechanisms efficiently facilitates the access to idle financial resources, and it acts as an intermediary between the savers and investors by mobilizing funds and making it available to firms for productive use. In line with the traditional finance, the essence of an efficient capital allocation in an economy should be invested in high-profit sectors and withdrawn from sectors with poor expectations. The question that arises here is whether in accordance with the paradigm of sustainable development, the allocation of financial resources to the most profitable investments can serve to meet the objectives emerged from this new paradigm. The functions of a financial market promoting sustainable development are: mobilizing savings and raising capital and channelling it towards projects that are in line with Environmental, Social, and Governance (ESG) criteria; changing corporate vision by incorporating ESG criteria into the management best practice through conditioning their access to finance; influencing good corporate practice that promotes sustainable development through the ownership mechanism (Stoian and Iorgulescu, 2019). However, Busch, Bauer and Orlitzky (2016) pointed out that although financial markets incorporate ESG criteria into investment decisions, in reality it does not seem that there has been a significant shift towards more sustainable businesses. A solution to this problem is provided by Lagoarde-Segot (2019) who restates the important role played by the higher education institutions, academic research and finance disciplines in aligning financial institutions and market participants with the long-term decision-making process required to finance the sustainable economy and society.

Despite the efforts made, recent evaluations show that for many of the Sustainable Development Goals (SDG) targets set by the Agenda 2030 the progress is quite slow indicating the likelihood that these objectives will not be achieved in the end (Eurostat, 2020). We believe that in order to succeed in achieving them and building a society based on sustainable development, profound changes of the mindset are needed. We need to change the way we think and act.

Keywords

Sustainable development, sustainable finance, economic growth, capital market, return, risk

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Presenters Profile

Andreea Stoian is a Professor of Finance at the Department of Finance in the Faculty of Finance and Banking from the Bucharest University of Economic Studies - BUES (Romania). She holds a PhD in Finance at BUES. Since 2012, she is the Head of the Center for Financial and Monetary Research (CEFIMO) at BUES. She was a visiting scholar at Universite Paris 1 Pantheon-Sorbonne (CES), Universite Libre de Bruxelles (DULBEA) and Universidade do Porto (FEP) and an Erasmus guest lecturer at University of Poitiers, University of Bordeaux and University of Orleans. Andreea Stoian is the First Vice-Chair of the International Network for Economic Research (INFER), co-founder of the Romanian Association of Finance and Banking (RoFIBA) and fellow of the Monetary Research Center at the University of National and World Economy (Bulgaria). She is also the Executive Editor of the Romanian Journal for Fiscal Policy (RJFP). Her main research interests are in fiscal policy, mainly focused on fiscal sustainability and vulnerability, public debt and budget deficit, but also on financial markets and sustainable finance. She published in: Economic Modelling, Eastern European Economics, Empirica. Journal of European Economics, Applied Economics Quarterly, Czech Journal of Economics and Finance, Managerial Finance.

Filip Iorgulescu is a Lecturer at The Bucharest University of Economic Studies, works as a senior economist for The Romanian Fiscal Council and is a researcher associated with The Center of Financial and Monetary Research (CEFIMO). He holds a PhD in Finance from The Bucharest University of Economic Studies and between 2014-2015 he received a post-doctoral scholarship for studying risk transmission in financial markets. His main research interests and teaching areas focus on sustainable public finance, fiscal policy, financial markets and risk management. He was a visiting researcher at Universidad Complutense de Madrid (2014) and an Erasmus+ teacher at Université d'Orléans (2016), Tashkent Financial Institute (2017) and Université de Poitiers (2018).

How can remote sensing support agricultural policy?

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Abstract

Agricultural policy instruments often lack effectiveness. Digital technologies promise to provide new options to increase effectiveness of agricultural policy. Among them remote sensing features prominently, especially for monitoring farming impacts and compliance with policy requirements. However, it is not clear how much difference remote sensing applications can make to agricultural policy. Limits and scope of remote sensing applications to support agricultural policy have not been consistently established. This paper provides a systematic analysis of limits and scope of remote sensing applications to support agricultural policy, drawing on policy and project reports as well as research literature. The current paper presents work in progress. The analysis identifies specific agricultural issues where remote sensing can already make a difference, such as identification of crop rotations and full-inversion tillage, and where promises of remote sensing are still limited, such as intensity of livestock farming and monitoring pesticide and fertiliser application. From these findings the analysis directly derives implications for the design of policy measures that use remote sensing. In particular, it can imply greater use of proxies for policy outcomes and compliance requirements that are unambiguously captured with remote sensing. The analysis also provides indications to where agricultural policy targets could move when remote sensing is used more widely to support agricultural policy implementation. Here, policy issues that can be monitored more efficiently with remote sensing could become preferential targets. Overall, remote sensing is found to affect future choices of targets and instrument designs of agricultural policy. Empirically, the current analysis focusses mainly on European applications, but most findings appear generalisable. Further research could address technological constraints of remote sensing applications for agricultural policy and generate more evidence on effects on agricultural policy.

Keywords

Remote sensing, agricultural policy, monitoring, evaluation, policy design

Presenters profile

Melf-Hinrich Ehlers is an ecological and institutional economist and a post-doc in the AECP Group of ETH Zürich. He has a great interest in analysing the formation and governance of renewable energy and farming innovations, such as those involved in smart farming. Currently he is mainly researching digital agricultural policy innovations. Melf held research and teaching positions at Humboldt University Berlin, the Ecologic Institute (Berlin), University of York and the James Hutton Institute (Aberdeen), where he covered agricultural, environmental and renewable energy policy analysis and business and sustainability management.

Fertilizer use in agriculture versus alternative environmentally friendly practices

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[B] *University Jaume I, Castellón, Spain*
[C] *Democritus University of Thrace, Komotiní, Greece*

Abstract

In the last two decades many countries have made an effort to limit greenhouse gases (GHG) in the European Union and globally. However, the efforts need to be intensified to avoid further deterioration of environmental quality. Agricultural practices could be detrimental for the environment due to the widespread use of fertilizers and pesticides. Chemical fertilizers pollute soil, water and crops, while biological fertilizers and mycorrhizal fungi could be reliable alternatives for improving soil productivity and plant growth in sustainable agriculture. We propose in this paper to analyse the use of pesticides and fertilizers in EU countries and in a global sample over the last three decades, compare it with the use of alternative environmentally friendly substances, that is biological fertilizers and fungi. In addition, we test for the existence of an environmental Kuznets curve to examine whether the increase in agricultural income is accompanied by a limitation in environmental degradation. This will indicate whether environmental quality is a priority for the farmers and will give us an insight on whether an environmentally friendly technology could be preferred. The proxy used for environmental degradation is the use of pesticides over the period from 1990 to 2017 from FAOSTAT and the proxy for economic performance is agricultural income per capita for rural population over the same period.

Keywords

Fertilizers; pesticides; fungi; EKC; agricultural income

Presenters Profile

Professor Inmaculada Martínez-Zarzoso (orcid.org/0000-0002-3247-8557) is Apl Professor at the University of Göttingen (Germany). Her fields of research include international economics and development economics. She is the author of two books and of more than 80 articles in academic journals including the Journal of International Economics and the Review of International Economics.

Acknowledgement

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Keynote Presentation: Leveraging Yield Response Information from Dense Field Data: A Comparison of Local Regression Methods

Dayton M. Lambert

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Abstract

The beginning of the 21st century witnessed a cross-fertilization between spatial econometrics and production economics with the estimation of site-specific yield response functions. Partial budgets compared returns to site-specific or uniform nutrient management using statistical models that controlled for the autocorrelated nature of agronomic data. The models typically used estimated the overall mean response to inputs. Interestingly, at this time researchers paid little attention to regression techniques that produced spatially varying coefficients. Spatially varying parameter models are well-suited to the dense data layers produced from yield monitors, remote sensing, and other precision data. There are several local regression approaches, including geographically weighted regression, spatial expansion regression, and spatially adaptive filters. Recent approaches capable of producing spatially varying parameters include Bayesian spatial kriging estimators and spatial Gaussian process models. The performance of these estimators is compared using data from a nitrogen strip trial for corn. The findings have implications for choosing regression-based estimators that leverage the most information embedded in dense spatial layers to make input management decisions. From the end-user's perspective, what really matters is not only the accuracy of statistical predictions to make informed managerial decisions, but also algorithm feasibility in terms of computational time and unambiguous output.

Presenters profile

Dayton Lambert is a professor and Willard Sparks Chair in Agribusiness at Oklahoma State University Department of Agricultural Economics. Dr. Lambert's research interests are production economics, regional economics, decision theory, and econometrics. He holds a joint research and teaching appointment. He received a Ph.D. in Agricultural Economics from Purdue University. His research focused on precision agriculture and the development of statistical models to estimate site-specific crop response to inputs. His current research program focuses on the role of information for strategic and tactical decision-making for rainfed cropping systems, the effects of conservation policy on land use decisions, and structural changes in the US dairy sector.

The Role of Contractors in the Uptake of Precision Farming – A Spatial Economic Analysis

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Abstract

Contractors will play a vital role in providing farms access to new precision farming technologies, especially in small scale farming systems. Yet the current development of precision farming uptake by small scale agriculture requires support from effective policy interventions. We investigate the role of contractors and their spatial competition in the uptake of precision farming, the distribution of farmer surplus, and the effects of policy intervention, accounting for different pricing schedules. Conceptual analyses and simulation show that a lack of spatial competition among contractors decreases both the uptake of precision farming technology and farmer surplus in the uptake. Moreover, a lack of competition renders a subsidy on precision farming practices less effective in improving uptake and farmers' welfare. Furthermore, a spatially discriminatory pricing schedule supports higher uptake of precision farming technologies and greater effectiveness of a subsidy in increasing uptake compared to spatially non-discriminatory pricing. The extent to which public benefits of precision farming can be achieved and the effectiveness of policy interventions promoting precision farming technologies therefore depends on the spatial market structure of contractors and their pricing strategy.

Keywords

precision farming, technology uptake, contractor service, market structure, spatial competition.

Presenters profile

Yanbing Wang is a postdoctoral researcher with the Agricultural Economics and Policy Group at ETH Zurich. Her current research focuses on understanding factors and mechanisms associated with adoption of environmentally sustainable agricultural technology and practice. Her general research interests are in agricultural and environmental economics, with other research topics covering land use change and sustainable investment.

Using on-farm precision experimentation to optimise seed and nitrogen fertiliser rate management in the Free State, South Africa

Marion Delport[AB], Brittani Edge[C], David S. Bullock[C], Michael van der Laan[A] and Robert E. Dunker[C]

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[C] *University of Illinois, Urbana-Champaign, Illinois, United States of America*

Extended Abstract

The past decade has witnessed a revolution in precision farming technology and access to big data. The coming decade may lead to major efficiency gains through the successful application of big data information. On-farm precision experimentation (OFPE) uses precision technology to inexpensively design and run randomized agronomic field trials on whole commercial farm fields (Bullock et al., 2019). In so doing, it generates vast quantities of high-quality agronomic field trial data for empirical research and site-specific agronomic input management (Bullock et al., 2019). This article reports the methodology and analytical results of a 56 hectare maize OFPE with randomised trial designs for nitrogen fertiliser (N) application and seeding rates, cooperatively conducted in 2019/2020 by South African researchers and the US-based Data-Intensive Farm Management project (DIFM) in the Free State province of South Africa.

The participating farmer reported a status quo seed rate ("business-as-usual" – the rate at which he would have planted the field if not participating in the research) of 18K seeds ha^{-1}. He predicted that the yield maximizing seed rate would be 30K seeds ha-1. The randomised design included five seeding rate treatments, each between 10K and 50K seeds ha^{-1}. He reported that he usually applied 90 kg N ha^{-1} at pre-planting, 200kg N ha^{-1} (15:10:6) at planting, and an additional 90kg ha^{-1} as a top dressing. The pre-plant and top-dress doses were applied at their status quo rates, but at planting, five rates between 90 and 270 kg ha^{-1} were targeted at the rates assigned by the N trial design. Figure 1 illustrates the seed trial design and the as-planted seeding rate data.

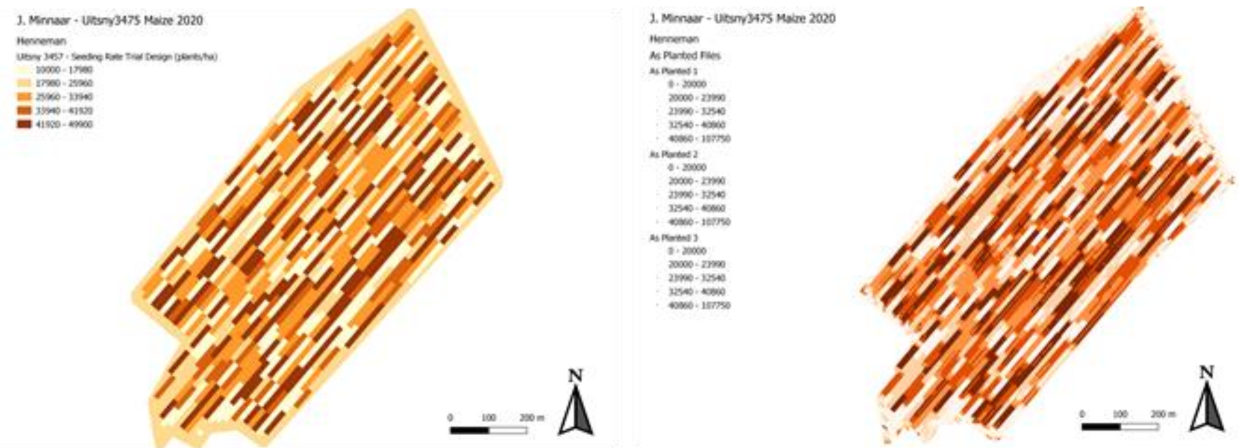

Figure 1: Left: Variable seeding rate trial design Right: As applied variable seeding rates

The trial plot received sufficient and timely rainfall (530 mm over the growing season) and a good harvest was achieved with an average yield of 9.6 t ha^{-1}. The processed ('cleaned') data resulted in 6025 "trial plots" containing consistent treatments (seed rate and N application) and corresponding yield (see Figure 2). A generalized additive model (GAM) was used to estimate the yield and profit curves by relating the variable seeding and N rate to the observed yield, and profit calculated.

Figure 2: Cleaned yield data illustrating the 6025 trial subplots

The profit maximising seeding rate was 29 316 seeds ha^{-1}, and the selected optimal N rate at planting was 234 kg N ha^{-1}. While the profit maximising N rate was the highest rate (259 kg ha^{-1}) (Figure 3 and Figure 4), the gains in profit above 200 kg ha^{-1} were only modest. Profits at 210 kg ha^{-1} were R17128[1], while profits at 274 kg ha^{-1} are R17179, for a R51 difference. Thus, the lower rate may be better when considering risk and environmental contamination.

Table 1 compares the profit calculation using the business-as-usual rates with the estimated profit maximisation rates. A significantly higher profit can be realised by increasing the seeding rate from 18 000 to 29 613 seeds ha^{-1}, which will result in a 65% increase in seed costs and a 17% in total profits.

For future research it is recommended that financial model simulations are also used to quantify the optimal seeding and N application rates given the risk impacts of higher cost, and that the trial is repeated on the same field in the 2020/2021 season in order to evaluate the impact of environmental variables including weather on yield and profit maximisation, as well as financial risk management.

[1] The rand (ZAR) is the official currency of South Africa.

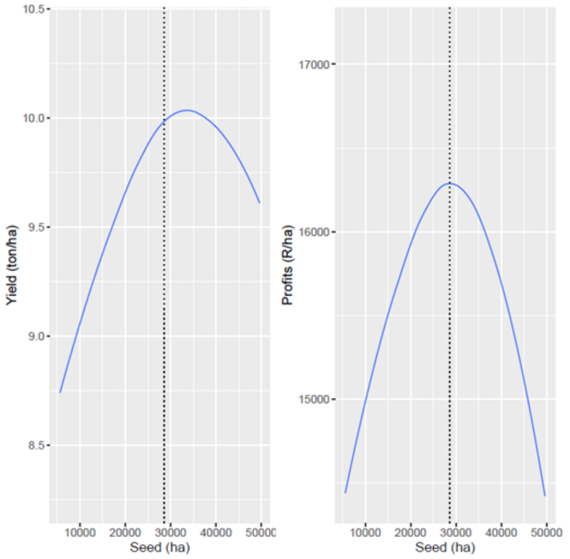

Figure 3: Left: Yield response to seeding rate Right: Profit response to seeding rate

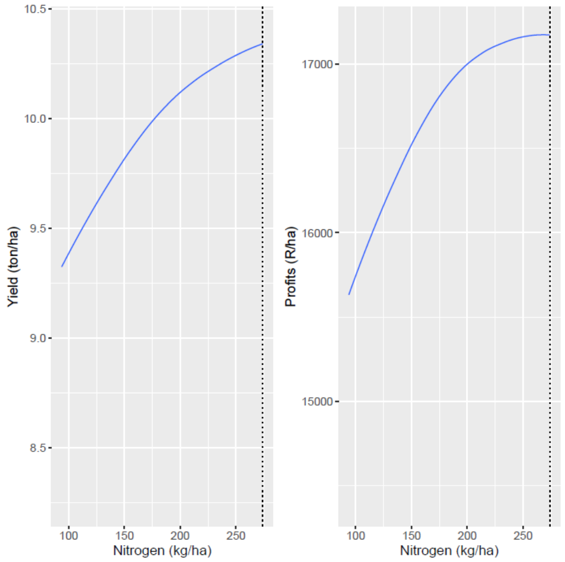

Figure 4: Left: Yield response to nitrogen rate Right: Profit response to nitrogen rate

Table 1: Profit calculations

	Cost	unit	Usual Rate	R/ha	Profit Maximisation Rate	R/ha
Seed	2 813	R/60 000 seeds	18 000	843.90	29 613	1 388.36
Urea	4 712	R/ton	200	942.40	234	1 102.61
Remaining direct costs	3 898	R/ha		3 898.00		3 898.00
Overhead (indirect) costs	1 947	R/ha		1 947.00		1 947.00
Total Cost				7 631.30		8 335.96
Average yield		t/ha	9.00		10.25	
Average farmgate price		R/ton	2 351		2 351	
Average Revenues				21 159.00		24 097.75
Average Profit				**13 527.70**		**15 761.79**

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Keywords

On-farm Precision Experimentation, yield response.

Presenters profile

Marion Delport is the manager for the Data Science division at the Bureau for Food and Agricultural Policy (BFAP). Her current position involves data analytics and maintenance, supporting internal skills development and offering modelling and data analysis support on various BFAP projects.

She completed her Master's degree in Mathematical Statistics at the University of Pretoria (2017) and spent time at the United Nation's Food and Agricultural Organisation (FAO) as well as the Organisation for Economic Cooperation and Development (OECD) in 2015 and 2017. She has also presented her work at the Conference of the South African Statistical Association as well as the Agricultural Economics Association of South Africa Conferences.

An Economic Evaluation of Site-specific Input Application R_x Maps

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Abstract

Numerous commercial software "decision tool" systems, which generate site-specific crop input management recommendation maps ("prescriptions"), have now appeared on commercial markets. But farmers and professional crop advisors remain sceptical about whether purchasing and following prescriptions can increase farm profits. This study proposes a method to empirically evaluate the efficacy of such commercial site-specific prescriptions. The proposed method requires three steps: (1) to use precision agriculture technology to conduct a randomized on-farm field trial; (2) estimate yield response functions for the prescription's "management zones" using the resultant experiment's data; and (3) conduct economic analysis to judge the effects of implementing the prescription on profitability. The procedure is illustrated using data from a nitrogen and seed rate experiment run on a 31 ha Ohio field in 2018, for which nitrogen and seed prescriptions were created by the farmer's professional consultant. The analysis concludes that the consultant recommended a higher nitrogen application rate for the zone with a smaller economically optimal nitrogen application rate, implying that implementing the nitrogen prescription would have significantly lower profits. However, recommended seed rates were almost identical to the estimated economically optimal seed rates.

Keywords

Site-specific input management, nitrogen rate, seed rate, on-farm randomized field trial, shape-constrained generalized additive modelling, economically optimal input rates.

Presenters profile

David S. Bullock is a Professor in the Department of Agricultural and Consumer Economics at the University of Illinois. He received his Ph.D. from the Department of Economics at the University of Chicago in 1989. The major focus of his current research is on the economics agricultural technology and information. He is the Principal Investigator of the four-year USDA-sponsored "Data-Intensive Farm Management" project, which uses precision agriculture technology to conduct large-scale, on farm agronomic experiments, to generate data that improves farmers' management of nitrogen fertilizer and other inputs. Bullock has published widely in prestigious economics, agricultural economics, and agronomy journals, including the Journal of Political Economy, the American Journal of Agricultural Economics, and Agronomy Journal. He teaches PhD courses in microeconomic theory, and has been cited numerous times for outstanding instruction of graduate courses. He has been publishing research on the economics of precision agriculture technology since 1998.

Marginal opportunity costs of nitrogen fertilizer with respect to response functions

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Abstract

Nitrogen (N) fertilizer is an important farm input and indispensable to feed the growing world population. However, undesirable emissions of chemical compounds of N cause significant threads to ecosystems, climate change and human beings, which forces governments to regulate the use of N in agriculture. In Germany, legislation has enforced a regulatory framework, which fixes the limits of N use in agricultural farms. While the regulation basically regulates the use of N fertilizer based on the needs of the plants, in so called “vulnerable zones” with high nitrate levels in the groundwater, N fertilizer use is restricted to 80 % of the needs determined in the regulatory framework.

The restriction in N fertilizer use obviously results in opportunity costs for the farmer, which can be calculated with yield response functions. However, it has been shown that for a given fertilizer –crop relation different response functions may be appropriate resulting in diverging opportunity costs of reduced fertilizer use (Cerrato & Blackmer, 1990; Henke et al. 2007). Due to the different shape of the production functions, the marginal opportunity costs of the production functions differ substantially. Typically, based on the same data the economic optima are substantially lower with linear-plateau production functions than the optima for quadratic and quadratic-plateau functions. The relation between economic optima of different response functions is illustrated in Figure 1 for the quadratic and the linear-plateau function. While the economic optimum (profit maximum) for the linear-plateau function is either fixed at the kink of the function or at zero, when the slope of the function is lower than the marginal economic return of the fertilizer input. The economic optimum for the quadratic function is subject to crop and fertilizer price and typically varies according to prices as indicated in the graph. Typically, the impact of the choice of response function has a higher impact than the cost-price relationship as can be seen in Figure 1.

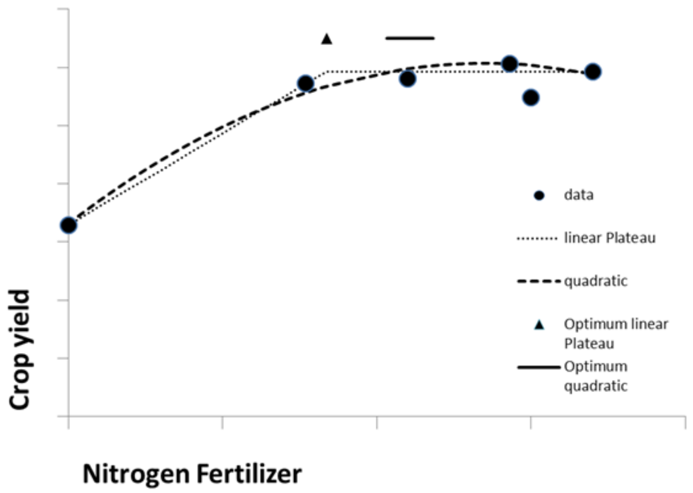

Fig. 1. Typical relation between economic optimum of a linear-plateau function and a quadratic function based on the same data from an experiment with six fertilizer levels.

The marginal costs of reduced fertilizer input obviously differ between the considered production functions. From theory, for a continuous response function the marginal costs of N reduction are zero at the economic optimum since marginal costs meet marginal benefits at the economic optimum. In contrast to continuous functions kinked functions like as the linear limitational function have constant marginal costs for fertilizer reduction cost, while the marginal costs of N reduction for the linear-plateau function at the economic optimum is a function of the slope of the function.

The confusion about different response functions with their optima and marginal response provides opportunities for using the one or other response function to argue for high or low costs of N fertilizer reductions, respectively. Besides the shape of the response function, it has been shown that quality aspects, which affect crop price may have a huge impact on economically optimal fertilizer rates and on marginal opportunity costs of reduced fertilizer application (Meyer-Aurich & Karatay, 2019), which further complicates the identification of costs for N fertilizer reduction. This paper elaborates on the consequences of using the one or other production function on marginal opportunity costs of nitrogen fertilizer use based on empirical data from field experiments in Brandenburg, Germany. The findings provide challenges and conclusions how response functions can be used to assess opportunity costs of nitrogen fertilizer use in agriculture.

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Meyer-Aurich, A., Karatay, Y. N., 2019. Effects of uncertainty and farmers' risk aversion on optimal N fertilizer supply in wheat production in Germany. *Agricultural Systems*. 173, 130-139.

Keywords

Nitrogen management, response function, uncertainty.

Presenters profile

Dr. Andreas Meyer-Aurich holds a PhD in Geoecology (Universität Potsdam) and habilitated in agricultural economics at the Humboldt University in Berlin. His research focuses on economic and environmental effects of technologies in agriculture. A special focus is set on fertilizer use in crop production with respect to uncertainties of crop yield response. He is an active member of the German Society of Informatics in Agriculture (GIL) and the advisory group of the Global Institute of Agri-Tech Economics at Harper Adams University. Currently he is employed at the Leibniz-Institute for Agricultural Engineering and Bioeconomy.

Exploring attitudes to technology adoption for cross compliance in Greek and Lithuanian farmers

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[B] School of Life Sciences, University of Herefordshire, Herefordshire, UK

Abstract

The fourth agricultural revolution has started with an explosion of online, smart, digital technologies that are now available to support farmers to improve their operations is enabling opportunities for direct integration between agricultural and computer-based systems. However, the wide range of devices and applications available can be overwhelming and the farming community is showing reluctance to adoption of these new technologies. As part of an EU-funded, multi-partner research project we developed, in collaboration with farmers and other stakeholders, a novel on-line system that supports EU farmers and paying agencies to reduce the administrative burden of CAP's cross compliance record-keeping and inspections. During the co-development phase we interviewed Greek and Lithuanian farmers about their user needs in relation to the novel system and their potential adoption of this new technology. We analysed their qualitative responses and could identify two groups; 'Optimistic' and 'Reluctant' in relation to their use of novel technologies. In order to achieve up-take of new technologies within the European farming community, we considered these findings using the Theory of Planned Behaviour and concluded that focussing on the ease of adoption and peer usage would encourage the highest adoption rates as opposed to focusing on changing farmer attitudes.

Keywords

Digital Technologies, Theory of Planned Behaviour, co-development, technology adoption

Presenters Profile

Dr Yiorgos Gadanakis is an experienced analyst, proficient in data management, analysis and interpretation. His research focuses on the analysis of agricultural production systems in terms of technical and economic efficiency incorporating the relationship between environment and agriculture. His recent work on sustainable intensification and water use efficiency aims to improve the management of farm businesses and to reduce the environmental pressures generated at farm level. In addition, he has been engaged with a range of EU funded research programmes and has specialised in model development using both quantitative and qualitative analysis to attribute monetary values to certain aspects of sustainability.

Introduction

On-farm inspection is time consuming and expensive for member states (Pluto-Kossakowska et al., 2013). The high number of sites and farm businesses to inspect and so many regulations to comply with, infringements are frequently detected and in a recent EU audit between 20 - 29% of inspected farmers and businesses were found to have areas of non-compliance in the years 2009 - 2015 (European Court of Auditors, 2016). Even among farmers that are engaging with voluntary systems such as organic farming, there is a high rate of infringements, for example German and Italian organic farms were found to have a 15 % non-compliance rate (Gambelli et al., 2014) and farmers engaging with voluntary assurance schemes in the UK had an 11% non-compliance rate for animal welfare rules compared to 22% for farmers not involved in voluntary schemes (Clark *et al.*, 2016). With thousands of farms submitting applications for their Basic Payments to their paying agencies every year, the administrative burden of the rural payments system is high. As a result, EU governments are looking to alternative methods to reduce this burden. One method suggested includes the use of new digital technologies that deliver results derived from advanced machine learning and analysis of satellite images.

This article draws on a multi-country research project undertaken as part of an EU H2020 innovation grant aimed at reducing the costs of public administration of the CAP. The EU-funded RECAPi project – peRsonalised public sErvices in support of the implementation of the Common Agricultural Policy - proposed a methodology for improving the efficiency and transparency of compliance monitoring through a cloud-based Software as a Service (SaaS) platform to use the large volumes of publicly available data provided by satellite remote sensing and user-generated data provided by farmers through mobile devices (such as geo-referenced and time-stamped photos). A web-based portal would serve as a digital replacement for filling in mandatory paperwork required under cross compliance and would reduce the number of on-farm checks, with inspectors able to confirm compliance remotely by looking at remote sensed images of farmer holdings. Furthermore, the project sought to co-produce such a system with farmers, paying agencies and agricultural consultants with farmers contributing to the project in a series of user needs exercises, the first starting in 2016 with a series of semi-structured interviews. Through these interviews a theme began to emerge around farmer attitudes and abilities to adopting new technology. Socioeconomic barriers are important barrier to EU farmers – which can mean that supply side innovation is inadequate to drive adoption of new technologies (Long et al, 2016). Furthermore, the limited options in college education regarding digital agricultural technologies and their use in farming production systems and decision making are also a barrier to farm level adoption (Reichardt & Jürgens, 2009; Tiffin & Balcombe, 2011). Another barrier investigated previously is that social factors are often not considered when farmers are encouraged to adopt new technologies (Kutter *et al.*, 2011). Thus, these barriers were considered in the RECAP project and was the main reason for the user needs analysis work to ensure that the technology was suitable for all end users. The co-production approach ensured that all stakeholders were involved throughout the interactive, agile development phase. However, there is a much broader range of farmers who may end up utilising this platform and their potential adoption of this technology was investigated using Theory of Planned Behaviour approaches to changing behaviours. This article reports on the qualitative findings of the 2016 user requirements data collection phase of this project. It draws on the literature on attitudes and decision making with Azjsen's psychology-based Theory of Planned Behaviour approach.

Methods

The analysis presented here focuses exclusively on a series of semi-structured interviews conducted early in the project in 2016 with farmers in Greece and Lithuania with a user needs exercise to establish what web-based functionality and agricultural inspection areas were needed in a web-based compliance system. An interview protocol was developed to answer two main questions:

1. What were the farmers' needs for new technology in the form of an electronically based record keeping system to support cross compliance?
2. How keen were farmers to adopt this new technology and what potential risks and benefits did they foresee in the development and application of this new technology?

The first question focused on the farmer needs in terms of technical elements of a web-based record-keeping system to support cross compliance, i.e. do they have internet access, do they use personal computers or smartphones and how comfortable are they with these things. The second question is more theoretical and linked to Theory of Planned Behaviour. See Supplementary Information Annex 1 for full interview protocol.

The interview material was developed by the University of Reading team who trained the interviewing staff on interview technique, obtaining consent, respecting anonymity as well as the content of the interview. Interviews were conducted on-farm, with paying agency staff interviewing farmers who had been inspected within the last three years. Fifteen farmers in Lithuania and twelve in Greece were interviewed in their native language. The interviews began with a series of closed questions about the farm and the farmer's demographics followed by two series of semi-structured interviews with open-ended questions aiming to stimulate discussion about how farmers use technology and whether they were keen to see this change occur. The interview structure required that the interviewer had a good knowledge of the specific agricultural area and its relevant challenges.

The interviewers asked farmers structured questions about; their engagement and experience with technology, whether they had access to desktop PCs, laptops and/or smartphones, and whether they had access to a reliable broadband network on their farm. They also asked whether farmers kept electronic or paper records of their farm's activities as well as demographic information about themselves and their farm businesses. The interview then introduced pictures of key stages in the process of using satellite images in the not-yet-developed cross compliance platform. These images prepared the interviewees for a stage of semi-structured questions exploring problems they had encountered with cross compliance and solutions they could recommend. Interview length was variable and lasted between twenty minutes to one hour due to the unpredictable nature of semi-structured interviews and open-ended questions. Interviews were transcribed and translated by native speakers of Lithuanian and Greek at the University of Reading.

Qualitative analysis was thematic analysis of the sort described by Braun and Clarke (2006) where 'codes' are applied to excerpts of interview transcripts. It is a way of identifying recurring patterns in a heterogeneous dataset (in this case words freely spoken) where codes are short, summative words or phrases applied to a longer passage to capture something essential about the excerpt (Saldaña, 2013). The qualitative analysis was conducted by a first coder from the University of Reading team with the English translations using NVivo (NVivo qualitative data analysis software; QSR International Pty Ltd. Version 12, 2018). A second coder on the University of Reading team coded two interviews independently of the first coder. They compared their codes, developed a code book together (as suggested by Saldaña, 2013) and the first coder underwent a second stage of qualitative analysis re-coding according to the jointly agreed code book. Quantitative responses to the closed questions were stored in Microsoft Excel (2013), with statistical tests completed in R (R Development Core Team, 2013).

Results

Although reluctance and optimism were the main themes that emerged reading through the differences in these two groups, the Technologically Reluctant Group was not universally reluctant towards all technology. They were optimistic about the opportunities that technology provides and generally thought they themselves were competent at using technology, but thought other farmers were less competent than they were. The Reluctant Group thought about technology in an abstract way rather than specific way and focused on barriers and the bureaucracy of their paying agencies.

Discussion

Theory of Planned Behaviour suggests that attitudes, social norms and perceptions of control combine to create an intention; a precursor state to an action. Without favourable attitudes, social norms and perceptions of control, an intention is not created and action does not occur. This social-psycho theory is useful for explaining why change does not occur when attitudes are positive. It is also possible for attitudes, social norms or perceptions of control to be mixed and the other constructs to be positive or negative when creating a positive intention to change. In this study we saw two groups of farmers express mixed attitudes towards technological change, but the Reluctant Group also expressed pessimistic perceptions of their social norm and their ability to change by referencing the amount of bureaucratic barriers in their way to change. The Optimistic Group of farmers also expressed mixed attitudes towards technology but expressed positive perceptions of their social norm and their ability to adopt new technology. The Optimistic Group also demonstrated an ability to apply how this as yet undeveloped application would be used on their farm. This suggests that those working in farmer education and the provision and design of farm extension services should focus on the ease of technology adoption and the fact that their peers are using it as well to encourage greater adoption of new technologies.

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UK agricultural students’ perceptions of future technology use on-farm

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Abstract

Agricultural systems are currently experiencing a wave of new technological developments, which could lead to large and possibly disruptive changes in agricultural systems. So far, the adoption rates of new technologies have been highly variable, and attempts have been made to estimate adoption rates based on specific attributes of the technology and how it will be used, which can be difficult with new and emerging technology. An alternative approach is the Theory of Reasoned Action, published by Fishbein and Ajzen in 1975, which aims to explain how individuals will behave based on their existing attitudes and behavioural intentions and could be useful for examining the factors influencing adoption of future technologies. Current agricultural students are the farmers, researchers and rural professionals of the future. Their attitudes and beliefs towards technology will influence its integration into farming systems and how ethical concerns will have to be addressed. 300 current UK agricultural students participated in in an online survey; their perceptions around current and future agricultural technology developments were analysed using quantitative and qualitative methods. Results showed efficiency gains and improved management as the major perceived benefits of technology, while potential malfunction of and overreliance on technology were the main perceived risks.

Keywords

Theory of reasoned action, agricultural technology, on-farm, students’ perception, farm management, technology use

Presenters Profile

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Dr Victoria Westbrooke undertakes research area in farm systems, linking biophysical science and human/social research. In particular, ways of sharing knowledge and information within agricultural systems, future technology and farm scale. To date Dr Westbrooke has been a dairy farm consultant in both NZ and the UK and have also worked in agricultural research. Currently she is based at Lincoln University in Canterbury, NZ where she teaches farm management at both undergraduate and post graduate levels.

Introduction

Agricultural systems are currently experiencing a wave of new technological developments, which could lead to large and possibly disruptive changes in agricultural systems (Small, 2017). To date, adoption rates of new technologies have been highly variable (Miller, Griffin, Ciampitti, & Sharda, 2018). They are influenced, amongst others, by associated investment needs (capital, learning), existing infrastructure, farm size, perceived risks, and the type of technology (level of complexity) (Finger, Swinton, El Benni, & Walter, 2019), and depend also on farmers characteristics, such as beliefs, risk aversion, age, education (Pannell et al., 2006). While adoption rates can be estimated based on specific attributes of the technology and how it will be used (Kuehne et al., 2017), it is difficult to estimate this for new and emerging technology. An alternative approach is the Theory of Reasoned Action (Fishbein & Ajzen, 1975), which aims to explain how individuals will behave based on their existing attitudes and behavioural intentions and could be useful for examining the factors influencing adoption of future technologies.

Workforces are changing and increasingly diverse with preference for variety, flexibility, and ongoing upskilling; recently there are initiatives trying to build on this, such as DairyNZ's New Workplace Design project (DairyNZ, undated). Agricultural students are the workforce of the future and their attitudes and beliefs towards technology will influence its adoption on farm. The aim of this study was to explore future agriculturalists views on the role of technology in farming systems, by investigating the following research objectives;

1. Identify and describe students' previous experience with agricultural technology.
2. Identify areas or tasks that students' value on farm (high job preference) and assess the beliefs and attitudes associated with them. Explore areas and tasks that students identify for technology to take over (low job preference). Focus on job satisfaction.

The research focussed on technology used in the operation and management of farms that is 'inside the farm gate' in the United Kingdom, with the potential to include other countries in future studies. Four types of technology were analysed: 1. Mobile phone applications (recording, collating and sharing of data), 2. Weeding robots and / or drones (autonomous weed control in pasture and crops), 3. Sensors which capture and analyse data (such as livestock collars, or sensors in combines), 4. Swarm robotics taking over farm operations (farmers role mainly to maintain robots and deal with non-standard problems).

Methods

An online survey was undertaken between 4th and 26th November 2019. Students studying agriculture and related topics at Harper Adams University were invited to participate. The survey gathered information on the students' background (age, gender, exposure to farming) and future plans (preferred job, subject area and sector). Students' views on four different types of agricultural technology (mobile apps, drone/robot, smart sensor and swarm robotics) were explored by asking the students' overall view of the technology, their level of knowledge of the technology and how they believed the technology would impact on different aspects of the farming system. The questions were either short answer or statements; the respondent was asked to rate the degree of agreement with a statement based on their experience or view. A Likert style scale from 1 (a great deal) to 5 (not at all) with word anchors at each point was used, based on trial students' rating preferences. The questionnaire was designed to take between 10-15 minutes. The project was approved by the Harper Adams Human Ethics committee, 15 October 2019. The data was analysed using SPSS (Statistical Programme for

Social Science, IBM) and Nvivo (qualitative data analysis software, QSR International, version 12). The qualitative data from the short answer questions is reported in this paper.

Results

In total 301 students completed the online questionnaire, with 300 usable surveys obtained. The majority, 95%, of the respondents were between 18 and 21 years old, with a minority aged over 22 years. There was a slightly higher proportion of male (53%) compared to female (46%) respondents to the survey. Overall, respondents had a high level of experience on farms with the majority of respondents (70%) brought up on a farm. The majority of the participants (73%) had worked on one to three farms for more than a month, and 14% had worked on more than five farms. Less than 2% had not worked on farms. The majority (83%) of respondents plan to complete a bachelors level qualification (BSc Hons), after which almost half (47%) would prefer an on-farm role, with just under a fifth (19%) planning to work as a rural professional, and very few preferring research or public sector roles.

Of the usable surveys, the short answer questions obtained 103 to 261 responses each (61% average response rate). Main topics identified by coding of open-ended questions identified four key topics: Efficiency, work environment and skills, perceived risks, and employment.

Efficiency was the biggest perceived benefit of technology with 264 references. Important subcategories were time effectiveness, better recording of data, communication / sharing of information, and productivity increase, with 51, 36, 26, and 23 references respectively. **Work environment and skills** were mentioned in 202 references, with making jobs easier (40) and management (36) references making up the majority of remarks. In terms of management, references focussed on ‘improved, better, easier’ management, often through reduced time in monitoring, but also mentioned the need for “different style of management for most businesses” and a general “shift towards more management positions or duties”. Improved decision making (19), the need for different skills or knowledge (24), and tasks becoming more technical (22) were also frequently mentioned. 128 references were attributed to **perceived risks**. Views here were more widely spread, and are reflected in a higher number in sub-categories with fewer individual references, compared to previously identified topics. Above all, there seems to be a high concern for potential malfunction (28), followed by a feared overreliance on technology (18). A range of statements received between 11 and 5 references: less human interaction, the farmer seen as no longer farming, overcomplication, time consumption, increased loneliness, crime, lost skills, distraction, a disconnection of farmers to their work, and the fear of AI taking over. A reduction of standards, data privacy issues, noise, and a disconnection of consumers to farming received between 4 and 2 references each. In terms of **employment**, an interesting aspect was the clear distinction between labour reduction and unemployment, with some participants clearly expecting technology to cause unemployment (30 references), while the majority used the more neutral term of labour reduction (53 references), including a reduction in stress and workload, or freeing up hours to spend elsewhere on farm. 22 references were made to structural change, saying the new technology would “leave the older generation behind”, and “pushing the older generation and poorer farmers out of the market”. On the positive side, several references were made towards “attracting younger people” to agriculture with the increased use of technology.

Sentiment, costs and environmental aspects were also reported. Autocoding of the dataset suggested a relatively even spread of **sentiments**, with 144 positive (49 very positive and 95 moderately positive) and 141 negative (with 45 very negative and 96 moderately negative) statements. Individual coding revealed following concerns: Emotional concerns (8 references) were raised about the lack of direct relationship to the animals, and changing farmers' traditional lifestyles: "Slowly we are getting replaced by machines like in many other working environments." Students mentioned specific concerns of trust (4 references) towards automated equipment: "I'd trust a labourer to do the work more than a machine depending on the task." **Cost** related aspects were mentioned 58 times. While 27 references assumed a reduction in costs – 12 of those through a reduction in labour cost – another 27 expected an increase of costs, mainly through direct investment cost, but 4 references specifying increased training costs. In contrast, improved financials via increased profitability and competitiveness were only mentioned 8 times. There were 37 references on **environmental aspects**, which focussed largely on soil compaction, although reduced emissions and inputs were also mentioned.

Discussion

An initial challenge was the categorisation of technology into four distinct types, and to explain these with enough detail to clarify each type, while being open enough to allow for individual experience and association.

Survey results showed efficiency gains and improved management as the major perceived benefits of technology, acknowledging the need for additional training and a different style of management as well as a changed skillset for it to work. A wide range of potential risks were identified, with malfunction of and overreliance on technology being the main concerns. In terms of its impact on employment, participants' views ranged from a reduction of stress and freeing up time for other activities, to a more negative view of causing unemployment. While acknowledging the attraction of younger people into agriculture with increased technology use, concerns were raised about leaving the older generation behind and pushing them out of the market. The results confirm previous findings of ethical concerns (Eastwood, Klerkx, Ayre, & Dela Rue, 2017) and the need for more training for agricultural students (Eastwood, Klerkx, & Nettle, 2017). It is notable that environmental impact references were almost exclusively made with respect to cropping, not the livestock sector, where comments focussed on health and welfare aspects. This raises the question if there is less awareness of the environmental impact of livestock, or on how technology can improve it.

The perceived risks should be viewed in light of their emotional aspect, such as less human interaction, increased loneliness, AI taking over and increased disconnection. These concerns represent fears which will likely influence the adoption of technology in the future. They can also provide constructive input for both technology providers and the education sector to address accordingly.

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Age, technology adoption, and the agricultural productivity in the era of Agriculture 4.0

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Abstract

Agriculture 4.0 is a current agenda for both developed and developing countries as its benefits to increase the agricultural productivity are inevitable. The need to feed the world has been become an important issue in the global scene and the world must increase the food production more than 70% by 2050 (De Clerck et al., 2018). Therefore, food security is now considered as a part of national security. It is also noteworthy to mention that the negative impact of climate change on agriculture is under debate; first, severe reduction in agricultural productivity due to temperature increases, heat waves, droughts, unusual climate conditions may occur in near future. Second, natural resources have been becoming more scarce than ever due to climate change, therefore conventional usage of water, soil can be stressed as agricultural inputs. Thirdly, the conventional agriculture has been criticized to pollute the environment due to use of chemical substances and contributing to Greenhouse Gas releases (in animal husbandry); new developments in production must be integrated to sustain the reduction in pollution. To overcome these negative impacts of climate change on agriculture and increase productivity, Agriculture 4.0 offers solution while applying digitalization in the production process.

As is well known, neoclassical approach to production function takes capital, labour, natural resources, and entrepreneurs as the factors of production. In addition to debates regarding quality of factors not being taken into account and technology as being an exogenous factor, demographic characteristics of entrepreneur are also missing in the related literature. However, there is a long debate on the effect of farmer's age on the productivity in the agricultural production processes through several channels such as physical capital investment decisions and attitude towards innovations in agricultural technologies. It is argued that aging of the formers leads to a significant decline in the productivity because as farmers get older they become more conservative, lose their physical capacity, and become more reluctant to the application of new technologies (Tauer, 1984, 1995; Corner-Thomas, 2015). Moreover, studies show that younger farmers can highly contribute to economic performance and sustainability (Zagata and Sutherland, 2015; Brennan et al., 2016).

Since Agriculture 4.0 is the future of feeding the world and agricultural sector, and young farmers show higher capabilities in the adoption of new technologies this study aims to show the impact of age in technology adoption and agricultural productivity. Therefore, we utilize an extended version of the Cobb Douglas Production Function. Along with physical capital and labour, we add farmer as the entrepreneur weighted with an age factor. Furthermore, in different versions of the production function we incorporate several other variables such as usage of fertilizers, agricultural subsidies, and expenditure on research and development in order to control the effects of these factors.

In the second stage, on the basis of theoretical and empirical constructs we drive an estimable regression function from the extended production function. Incorporating the countries and time period for which data is available we set up a panel data model. By doing so, we investigate the effect of aging on agricultural productivity and examine country specific and time specific deviations. Empirical findings are expected to provide policy implications and suggestions for future agricultural policy design.

Keywords

Farmer age, Agriculture 4.0, Technological Adoption, Productivity

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Improved Rice Technology Adoption Decisions: What Roles do Time Preference and Spatial Dependence Play?

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Abstract

Genetically improved agricultural technological innovation enhances yield and food security. However, the rate of adoption of agricultural innovation has been slow in many developing countries. This may be attributed to many reasons including personal, group, environmental and climatic factors yet empirical evidence is limited on the roles of intrinsic factors in adoption decisions. This study examined the roles of time preference and spatial dependence in farmers' decisions to adopt high yielding rice varieties (HYV) in Nigeria using experimental and survey data and adopted two-stage modelling procedures, an instrumental probit. The structural time preference and adoption decisions models were simultaneously estimated. The finding suggested household size, male, friends and neighbours have negative effects on the decisions to adopt HYV while farmers living in rural agricultural zone have higher probability to adopt HYV. More importantly, instrumented by spatial dependence, impatience (low preference for the future) negatively affected farmers' decisions to grow improved rice varieties. It is concluded that both personal and group attributes especially spatial factors, as well as the observed (locations) and unobserved factors (environmental and climatic factors) drive rice farmers' adoption decisions. It suggests farmers' adoption pattern has some degree of heterogeneity attributable to both spatial and socio-economic factors.

Keywords

Agricultural technology, Decision making, Instrumental variable, Spatial dependence, Time preference

Presenters Profile

Omotuyole I. Ambali is currently a freelance researcher. He worked at Olabisi Onabanjo University, Nigeria between April 2010 and January 2020. He previously worked as Graduate Teacher with Ogun State Government, Nigeria and did his National Service after bachelor degree as Class Teacher in Government Day Secondary School, Dingady, Sokoto State, Nigeria. He currently holds a doctoral degree in Agricultural and Food Economics (2014-2018) obtained from the University of Reading, United Kingdom. He previously studied and bagged Masters' and Bachelor's degrees in Agricultural Economics and Farm Management from Federal University of Agriculture Abeokuta Nigeria in 2012 and 2008, respectively.

Introduction

Agricultural productivity growth is a panacea to food insecurity and poverty experienced globally. It is particularly important in developing countries where a large proportion of individuals are employed in agriculture which contributes greatly to the Gross Domestic Product (GDP). It enhances food availability and access not only at the household and national levels, but also makes excess food available for trading to earn foreign revenue. Notwithstanding, there are hindrances to the growth of agriculture in the developing world. Factors affecting productivity growth include imperfect products and financial markets, low extension services and slow rate of adoption of improved agricultural technology. Moreover, adoption of agricultural innovation is constrained by associated risk and uncertainty. Other factors explaining attitudes toward adoption include but not limited to farmers' and farm characteristics, technology attributes, institutional and community factors, social learning as well as preferences for time or attaching less weight to the present compared to the future. The later defines impatience or myopic view about future prospects. Several attempts have been made to identify the socio-economic factors that are drivers of farmers' adoption choices with limited attention paid to the intrinsic variables like time preference and spatial attributes. In other words, spatial factors like social and cultural norms, social networks, soil type, climatic and topographic conditions are either assumed exogenous or not accounted for in adoption models (Läpple and Kelley, 2015; Ward and Pede, 2015). This study therefore empirically examined the roles of time preference and spatial dependence in the decisions to adopt high yielding rice varieties (HYV) in Nigeria. Spatial heterogeneity may give insight not only to the pattern of adoption but also the diffusion of innovation.

Methods

This study used survey and experimental data collected from rice farmers across the 4 agricultural zones in Ogun State Nigeria. Farmers' time preferences were elicited using time delay choice lotteries to account for heterogeneity in decisions. The unobserved heterogeneity in adoption decisions was accounted for through the power distance spatial weights matrix by using the spatial lag of the time preference as instrumental variable in the adoption model. The adoption model was based on the conceptual framework assuming rice farmers face two technology choices (growing or not growing HYV). In this case, a binary probit may produce an inconsistent estimate when at least one variable is endogenous. Therefore, an instrumental probit was applied and estimated in two-stages to address this potential endogenous problem. This was simultaneously estimated with the time preference model first and adoption decisions model second. The potential sources of endogeniety include measurement errors in variables and omission of important variables (e.g. environmental factors) in adoption decisions model. Ignoring endogenous problem may lead to biased estimates and inference while accounting for unobserved variables in the adoption model will enhance policy on factors affecting the adoption of improved agricultural innovation.

Results

The results show that in addition to socio-demographic variables (household size, gender, friends, and locations), time preference or impatience is a significant variable affecting rice farmers' adoption decisions. It confirms previously reported findings on the importance of social network and spatial dependence in the adoption of agricultural technology (Läpple and Kelley, 2015; Ward and Pede, 2015). Impatient farmers have higher chance of adopting HYV compared to patient farmers. The effect of impatience on adoption decisions is aided by spatial dependence indicating a significant relationship exists between the level of impatience of a rice farmer and his neighbours. In addition, farmers living in the rural agricultural zones with associated low rainfall showed more willingness in adopting HYV compared to those living in the more climatically favourable urban agricultural zone. In summary, time preference instrumented by spatial dependence reduced the propensity to adopt improved rice varieties suggesting misleading inference is likely if spatial dependence is not controlled for in the adoption model.

Discussion

Spatial heterogeneity in attitudes may be attributed to many factors including socio-economic, geographical, ecological and climatic conditions of farmers' locations. These attributes may vary across agricultural zones suggesting inappropriate policy may be applied if spatial dependence effects and time preference are not accounted for in the adoption decisions model. The findings have many policy implications. First, farmers located in the less rainfall and rural areas should be targeted and encouraged to adopt improved rice varieties to enhance productivity and income. Provision of infrastructural facilities such as accessible roads would not only aid farming practices in the rural areas but also encourage the diffusion of technological agricultural innovation. Second, policy intervention that encourages the adoption and diffusion of HYV should not only be targeted at progressive farmers but also their neighbours. In the absence of modern infrastructure and amenities including functioning schools and low extension services, interpersonal communication and social networks can serve as effective tools for the diffusion of agricultural innovation. Third, development of agricultural technological innovation for farmers' acceptance should specifically focused on farmers' personal factors, perceptions about improved technology attributes, spatial and temporal factors. In conclusion, evidence of spatial dependence in time preference and adoption decisions suggests certain unobserved factors drive farmers' decisions to adopt or not adopt HYV. Identifying such variables may aid the acceptance of agricultural technological innovation. Further research should therefore seek to identify the unobservable spatial factors correlating with farmers' choice of improved farm practices.

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Guidance on using online videos and podcasts to improve farming practices

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Abstract

A new agri-environment scheme, 'Environmental Land Management', is being developed for implementation in England from 2024. The Department for Environment, Food and Rural Affairs has committed to 'co-designing' this new scheme with input from stakeholders, including through a nationwide network of 'Test and Trials', which are assessing package options, payment mechanisms, and the provision of advice. The successful delivery of free, targeted advice to farmers is a crucial component of the new scheme, but there are financial and logistical challenges in making available one-to-one, face-to-face advice for all farmers signing up to the scheme. Thus, there is interest in the use of technology to conduct knowledge exchange with farmers, such as online videos and podcasts, which research suggests can be useful forms of communication with farmers. Our study forms one of Defra's 'Tests' and specifically investigates the role of online videos and podcasts in knowledge exchange strategies, including user preferences on how they should be designed and delivered for maximum uptake. The study used mixed methods – a literature review, assessment of analytics information associated with Agricology management videos online, and a survey with 200 farmers. This talk focuses on the results of the literature review and analytics work, although it will report initial results from the survey. Our work so far has highlighted that there are a number of factors – such as length, delivery format, presentation style, farmer involvement, language, and relevance – which influences whether a video or podcast is watched or listened to, and ultimately whether it is likely to create positive behaviour change. We also discuss barriers and solutions for enabling the use of online videos and podcasts.

Keywords

Knowledge exchange; Knowledge transfer; Podcasts; Science communication; Videos

Presenters Profile

DCR is the Elizabeth Creak Associate Professor of Agricultural Innovation and Extension at the University of Reading, and alongside PhD student collaborators AdB and JS, works on a range of topics associated with agricultural innovation – knowledge exchange, adoption, and ethics.

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The use of blockchain technology to improve the food supply chain

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Abstract

The purpose of the article is to show how to use relatively new and very innovative Blockchain technology to improve the food supply chain. In countries such as the United States or Thailand is starting to be an indispensable element in the agri-food sector. At the outset, it should be said what the Blockchain technology is, the use of which is becoming very broad in many sectors of the economy, including in the area of monetary policy of the state. It is used when creating virtual money, i.e. cryptocurrencies, which, despite the controversy they arouse, as well as the world of virtual finance in the COVID-19 era, begin to play a significant role. Blockchain (BCT) in the case of the food supply chain, despite the fact that it is a relatively new digital technology, may revolutionize its functioning. This technology is designed to provide the possibility of storing information in a database of transactions and products, which is decentralized and distributed and not susceptible to changes and manipulations. BCT believes it can play a positive role in ensuring food safety and quality. The main benefit of using this technology is the increased transparency of food supply chains. BCT makes it possible to increase the efficiency of tracking systems and identification of agri-food products in the supply chain. This means that thanks to BTC, it is possible to reduce the number of cases of food adulteration and the unauthorized use of food quality certificates. Nevertheless, BCT, due to the fact that it is a new technology, is not fully developed, i.e. the possibility of scaling BCT may turn out to be ineffective in more extensive and complex supply chains including multi-component products. In addition, it should be remembered that this technology is associated with barriers of a social, economic, legal and financial nature, which may adversely affect the further use of BCT in food supply chains. Despite the growing interest of agri-food sector enterprises in using BCT, its implementation in food supply chains may progress slowly.

Keywords

Blockchain technology, agri-food sector, food supply chains, digital technology, agri-food enterprises

Presenters Profile

Professor Krzysztof Marecki and Dr Agnieszka Wójcik -Czerniawska are employees of the Warsaw School of Economics. As employees of the Department of Economics and Finance of Local Government, they deal with the issues of sustainable development in a very broad sense. In the area of their research interests there is both sustainable development in the field of renewable energy and issues in the area of finances, including finance technology, in which innovative financial tools such as Blockchain are related both to finances in the strict sense, i.e. cryptocurrencies and in the broad sense, i.e. to influence a number of economy sectors, i.e. agriculture, industry, services.

Introduction

New digital technologies are changing now the conditions for the functioning and competition of business entities in various industries and sectors of the global economy from the financial sector, through the processing industry and trade. The agri-food sector also increasingly uses the opportunities offered by the digital revolution. One of the digital technologies with a particularly high potential for the agri-food sector in the context of ensuring food safety and quality is Blockchain technology. This technology emerged at the end of the last decade in the wake of the global financial crisis in 2008 and 2009 as a response to a drastic decline in confidence in institutions involved in the regulation and supervision of financial markets. The main driving force behind the development of the Blockchain was the idea of bitcoin - a cryptocurrency functioning only on the Internet outside the control of the government and financial institutions [Klinger B., Szczepański 2017, p. 11-27]. Such an assumption cryptocurrency is breaking the paradigm of the central bank, which assumes that the issuance of money can only take place on the basis of centralized mechanisms, i.e. the only issuer of money may be the central bank. On the other hand, the idea of cryptocurrencies is based on Blockchain technology to create them in a distributed mechanism. The principles of operation of the new internet currency are described in the article "Bitcoin: A Peer-to-Peer electronic cash system", which was published in 2008 by a person or a group of people (no one know) using the pseudonym Satoshi Nakamoto [Nakamato S. 2018]. The proposed version of electronic payments was to enable online payments to be made directly between system users, without the need to register transactions by third parties. Shortly after the article was published, in January 2009, an open source program appeared on the Internet that generated the first 50 bitcoin block referred to as: genesis block. However, BCT is not only a technology that is limited to cryptocurrencies [Klinger B., Szczepański 2017, p. 11-27]. Thanks to a decentralized network of tens of thousands of computers, proof of work and trusted mechanisms of distributed transaction verification across these computers, Blockchain provides a secure structure for the storage and use of information and data. Blockchain can therefore be used to streamline any processes and activities that require information and data management. The technology can also improve the functioning of food supply chains, especially in areas related to agri-food traceability, origin, safety and quality [Smit H. 2017]. The first experiences and pilot projects show that the BCT has a significant potential to increase the transparency of the functioning of food chains [Ge L. 2017]. On the one hand, it can provide a reliable and tamper-resistant and forgery-resistant information path about the origin of products and food quality certificates, on the other hand, it can guarantee that the entities involved have an unchanged record of all completed transactions [Kasior K. 2018, p.19]. These benefits more and more often convince agri-food companies and companies from the advanced technology industry to implement joint, innovative projects on the basis of BCT [Galvin D. 2017].

Methods

This study uses materials from both English and Polish publications. The choice of such popular science publications in these languages is due to the fact that it is in the area of these countries, i.e. highly developed countries, that the issue of Blockchain technology, bitcoin and cryptocurrencies is more and more often discussed. In the case of compact materials, articles and publications from universities that deal with the broadly understood issues of it but examples from business practice will also be presented- USA, Thailand. The use of blockchain technology in these two countries is dictated by several variables. The United States of

America was chosen as an example for being the dominant world economy that largely sets global trends. Blockchain technology and the entire mechanism of activities in the area of IT or Fin-Tech, which blockchain technology approaches due to the best developed computerization in this country (Silicon Valley, IBM, Microsoft) seem to be the right choice. It is also worth emphasizing that the USA is a huge production market, but also a market for a number of products, including agri-food. The United States is the largest food producer in the world. The second selected country, Thailand, was chosen both because about 40% of the working population work in agriculture, growing rice, maize and sugar cane. Thailand exports mainly to Europe and North America: rice, tin and electrical equipment. On the other hand, unemployment in Thailand is around 1%, while the social inequality rate is one of the highest in the world: 53.6. Therefore, such an obvious counterweight to the USA and Thailand seems to be a perfect example of how technology is used in all developmentally different countries.

BCT applications in food supply chains

Blockchain technology can be used in various areas and fields, both related and unrelated to the world of finance [Creasey S. 2018]. The OECD [OECD 2018] divides the potential applications of Blockchain technology into three main categories:

1) Financial transactions - BCT can be unpermisssioned here, as in the case of Bitcoin, which provides everyone with the opportunity to participate in the chain, or permissioned nature, where only selected entities are entitled to register and check data in the book;
2) Logging and verification systems - in this category, Blockchain acts as a tool for creating reliable and unchangeable data and information records. You can indicate, among others on registers enabling the confirmation of property rights (e.g. to real estate), checking the origin and authenticity of specific items and goods, or verifying the authenticity of clinical trial results;
3) Smart contracts - BCT also allows you to attach additional data to transactions involving the exchange of funds or any other digital assets. The data added to the transaction are in fact computer programs that specify what conditions must be met for the transfer to be made. If the terms of the contract are met, the transfer is carried out automatically. Smart contracts therefore, they reduce transaction costs related to the involvement of third parties and legal service of transactions. They also increase the transparency of contract execution and minimize the time needed to complete the transaction.

The indicated properties of BCT make it a technology that can significantly facilitate and improve the functioning of supply chains of products and services to end recipient. In the agri-food sector, the use of BCT seems particularly possible and advisable. Blockchain solutions and applications take into account most of the problems and needs that arise in managing the flow of agri-food products between the individual links of the chain. These chains are now extremely elaborate and complex. They contributed to this, among others liberalization of world trade, increasing competition between enterprises in the agri-food sector as well as product and process innovations. Not only has the number of entities involved in the production, distribution and sale of food increased (thanks to the development of e-commerce), but also the number of food products offered. The extremely extensive and rich food offer for most consumers in the world currently includes simple and unprocessed products, multi-ingredient and highly processed products, conventional and unconventional products (e.g. genetically modified), ecological, meeting specific health requirements (functional food, superfood), and also having specific storage and distribution requirements [Kasior K. 2018].

The use of Blockchain in the food supply chain can already be observed both in Thailand and in the USA. In March 2019, Deputy Minister of Agriculture and Agribusiness announced that Thailand would apply Blockchain technology to food and agricultural supply chains to track down producers. At the time, they stated that the system is defined by using Blockchain technology and its application in the agricultural sector, where "consumers and authorities can track the origin of producers from their laboratories and farms, and their delivery to the factory, suppliers and users" [Thailand Ministry of Finance 2019].

The US Department of Agriculture has proposed to amend the rules on organic products. The purpose of these activities is to implement Blockchain technology to support the supply chain. On August 5, 2020, the U.S. Department of Agriculture (USDA) submitted its report. In it, he noted that they are making every effort to ensure that electronic systems such as (BCT) can be used in tracking the supply chain of organic products. “BCT can provide secure, verifiable, transparent and near-instantaneous traceability of supply chains. BCT can also protect confidential business information and trade secrets by automatically restricting data only to authorized entities. "Distributed ledger technology is a distributed database technology whose registers are replicated, shared and synchronized within the consensus of various geographically dispersed individuals, companies or institutions. It is predicted that future use of BCT may improve the flow of processes that use databases. We will have to wait for the use of the BCT. However, the agency acknowledged that the use of a new technology such as BCT would require additional time. The project must be fully completed and tested before it can be implemented in the organic food industry. “Unfortunately, there are several barriers that are slowing down the process of widespread adoption of the new technology. These include limited access to technology and connectivity in urban areas, widespread adoption of new electronic standards and high project costs ”. Growing consumer interest in healthy cuisine is revolutionizing the organic food industry. The need to improve the supply chain has never been seen before. Today, the fast-growing market boasts health-conscious consumers and a fast-growing market of retailers, broadcasters and distributors. Examples of using the supply chain. The report lists several corporations that rely on Blockchain-based solutions. The list includes Walmart, which uses a system to identify mango and pork in the supply chain, Nestle tests the Blockchain to improve its milk supply chain, and Bumble Bee Foods monitors the supply chain of yellowfin tuna from Indonesia.

It is worth noting that in the case of food, the frequent problem is contamination and contamination of food in many countries and regions, and they prove the limited effectiveness of the current system. An example is the infection of consumers with the STEC strain of E. coli in 2015, associated with the consumption of food in the premises of Chipotle Mexican Grill restaurants in the USA, which poisoned 55 customers [Kshetri N. 2018]. This event led to a sharp decrease in sales in this restaurant chain and a deep reduction in the value of the company's shares (by 42%). In part, the problem was caused by the heavy dependence of Chipotle and its related food purchasing companies on an extensive and less transparent supplier network [Kshetri N. 2018]. In some countries, unfair practices, including deliberate food adulteration, remain the primary cause of food incidents, and to a lesser extent human-independent equipment failure, technical accidents, pathogenic or pathogenic microorganisms present in food [Galvin D. 2017]. These problems are illustrated by the case of China, where from 2001 to 2013 there were over 49,500 incidents, the vast majority (68%)

of which resulted from the unethical behaviour of entities involved in the production, distribution or sale of food [Galvin D. 2017]. The costs of unfair practices are borne to a varying extent by actors in the food supply chain. Unfair practices also contribute to wider social losses in the economy. Blockchain, thanks to the function of creating unchanging records of events and processes, can provide greater transparency in supply chains and thus reduce the problem of unfair business practices. Blockchain technology could improve food tracking and identification systems in two ways. The first is to monitor the overall quantity of food in the supply chain (by controlling sales and purchase volumes), and the second is to track the path of individual agri-food products in the supply chain [Kairo 2017]. It is currently difficult to control the volume of sales and purchases of individual crops, such as beans, cocoa, coffee and many other raw materials. Recording all purchases and sales of agricultural products within the BCT would solve this problem and at the same time provide tools to monitor the actual composition of selected products. BCT would allow for quick and easy identification of false data on the quantity of a given commodity. As an example, illustrating the benefits of using BCT, there are transactions involving basmati rice - under the BCT, the volume of basmati rice sold cannot exceed the volume of basmati rice purchased by parties involved in the supply chain. Practitioners indicate that by controlling the overall volumes of agricultural products on the market, BCT would eliminate situations where an entity buys plain rice, mixes it with a small portion of basmati rice and then sells the entire batch as Basmati rice at a higher price. Such cases could be easily identified as the amount of basmati rice tracked by BCT and entering the supply chain cannot be greater than the amount that leaves the chain [Kairo 2017].

The second way to integrate BCT into food tracking, monitoring and traceability systems is technically and organisationally more complicated. Requires integration of supply chain transaction recording systems with data recorded on products using barcodes or QR codes, as well as data from Radio-frequency identification (RFID)[2] systems and other sensors placed on food facilities and packaging or other containers in which food is stored and transported [Tian F. 2017]. RFID technology has been used in the agri-food sector for a long time (including in the EU under the obligation to identify and register animals), but its capabilities are still not fully used in food safety and quality assurance systems. The tags and labels identifying given products or objects by means of radio waves can record data on events and processes within the entire agri-food chain - from the production stage (e.g. information on the variety of a given plant, place and time of sowing, methods and types of fertilization , while in the case of animals, among others, on the methods of feeding, drugs used, past diseases), at the processing stage (information on the type of product, amount and type of ingredients and additives used, weight, expiry date), at the distribution stage (information on the methods and conditions of storage and transport) and at the stage of sale (e.g. using information about the use-by date to monitor the product offer on store shelves / replace products on shelves) [Tian F. 2016]. Placing information from RFID tags in a counterfeit-resistant Blockchain, and ultimately also creating a cooperation platform between BCT and the Internet of Things, enabling communication between various sensors and sensors in real time, could significantly increase the effectiveness of the food safety and quality assurance system, especially within

[2] A technology whereby digital data encoded in RFID tags or smart labels (defined below) are captured by a reader via radio waves. RFID is similar to barcoding in that data from a tag or label are captured by a device that stores the data in a database. RFID, however, has several advantages over systems that use barcode asset tracking software. The most notable is that RFID tag data can be read outside the line-of-sight, whereas barcodes must be aligned with an optical scanner- http://www.abr.com

the framework of more extensive and complex supply chains. The main benefit of such a system would be not only to accurately identify the location of spoiled or contaminated food products or food batches that are hazardous to consumer health, but also to respond to hazards as they arise (thus potentially preventing specific food incidents and crises). At the same time, more advanced analytics of data collected within the BCT and the Internet of Things could, based on predictive algorithms, enable prediction of specific threats and incidents before they occur [Kasior K. 2018]. The use of Blockchain technology may also eliminate or significantly reduce the problem of fraud and falsification of food quality certificates [Ge L. 2017]. The emergence of organic food and food that meets the specific requirements and expectations of consumers has made the number of certifying institutions and the number of food quality certificates significantly increase in the recent period. Increasingly, certificates are used by food producers as an element of a marketing strategy (e.g. they build a brand image and potentially improve sales, the company's commitment to achieving sustainable development and environmental protection goals). Food products with a quality certificate are usually more expensive than their counterparts without similar certificates. However, their presence on the product is not always a guarantee of quality - cases of misuse of certificates with regard to products that do not meet the requirements specified by the certifying authority are not uncommon. Registering certificates in the Blockchain would allow for quick and easy verification of the authenticity and validity of certificates assigned to specific products and manufacturers. Certifying bodies after granting rights certificates could also authorize selected entities-organic farms to issue certificates on their behalf [Ge L. 2017]. As a result, BCT could limit the cases of unauthorized use of certificates, reduce transaction costs of the certification process (e.g. through the use of smart contracts) and reduce the administrative burden on certifying authorities. Greater transparency and credibility of the certificates could, at the same time, translate into their greater market value. In addition to the use of BCT to identify weak links in the food supply chain and to manage food quality certificates, the possible applications of BCT to create data repositories on the properties of agri-food products, production conditions, and environmental and socio-economic aspects of the functioning of agri-food chains should be indicated. The sources of this data in the Blockchain can be the previously indicated RFID tags.

Currently, many consumers, especially in developed countries, have very high expectations and requirements with regard to both nutritional information and information on the impact of agricultural production on the natural environment and living conditions of local communities. At the same time, consumers are increasingly looking for information on the products of interest to them and their properties not on paper packaging and labels of food products, but on the Internet and using special applications supported on mobile devices. This information is often unverified. Including an information pack on food products and their properties in the Blockchain would increase the quality and certainty of nutritional information for consumers. In the same way, information could be provided to consumers about the conditions of production and the terms of cooperation between the various links in the supply chain. Thanks to transactions recorded in the Blockchain, the consumer could quickly check whether the goods in his basket were produced in accordance with the principles of sustainable development and whether the farmer, who is most often the weakest link in the supply chain, was paid for it. In the long term, the use of BCT in the agri-food sector could therefore not only facilitate purchases, but also lead to more informed consumer choices and ultimately to more socially and environmentally sustainable food supply chains. [Kasior K. 2018].

Results

In summary, there are three potential application areas for Blockchain technology in food supply chains. These are: food tracking and identification systems; management of the certification process, including verification of the authenticity of food quality certificates; data repositories on agri-food products, production conditions and conditions of cooperation between the different links in the food supply chain, including monitoring of fair prices for farmers. The indicated activities taken together meet the growing needs in terms of ensuring broadly understood integrity in food supply chains [Hoorfar J. 2011]. According to this concept, activities for food safety and quality cannot be limited to technological and organizational aspects of food production and distribution, but should also take into account economic, social and environmental aspects related to the functioning of agri-food chains [Hoorfar J. 2011]. Blockchain, providing tools both for monitoring the flow of food products and their identification, as well as for recording other processes and events in the food supply chain, would allow a holistic approach to food safety and quality management. A significant problem in the context of the prospects for using BCT to ensure food safety and quality remains the extremely complex and varied regulations between countries and requirements for food products, and at the same time the lack of a common, international legal framework defining the conditions and principles of the digital economy. A barrier to the implementation of BCT in the food safety and quality management processes may be resources and financial means insufficient to undertake the required investments. It may be costly and time-consuming not only to transfer data and information from currently operating IT systems to the Blockchain, but also and above all to combine BCT with other technologies (including RFID) due to the still very high cost of labels based on this technology [Tian F. 2016]. The problem may also be large differences between individual countries and regions in terms of the possessed socio-economic and IT infrastructure. Today's food supply chains span many different countries, with varying levels of economic development and investment opportunities. The implementation of BCT within this type of chain can therefore be a big challenge. The main benefits and opportunities of managing food supply chains with the use of BCT include: greater credibility, transparency and certainty of information on agri-food products present in the food supply chain, reduction of costs related to the management of food incidents requiring the withdrawal from the market of the contested products, savings resulting from the reduction of food fraud and food quality certification, reduction of transaction costs due to the lack of necessity to involve intermediary institutions in tasks and processes related to ensuring food safety and quality [Kasior K. 2018].

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Potential demand for improved beef delivery services in Nigeria: Evidence from a discrete choice experiment

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Abstract

The objective of this study was to provide empirical information on Potential demand for improved beef delivery services in Nigeria: Evidence from a discrete choice experiment. We implemented a discrete choice experiment to gain insights into beef consumers' preferences for improved beef marketing services. This was implemented among a sample of 240 beef consumers across urban and rural communities in the research area. The analytical tools used to analyse the data was Mixed logit model. The results of the potential market for improved beef marketing services revealed that the attributes that were significantly related to the urban beef consumers preferences were freshness of beef ($p<0.01$), fatness of beef ($p<0.05$), certification of beef ($p<0.05$), retail outlet condition ($p<0.05$), and beef price ($p<0.05$). For the rural beef consumers, the significant attributes were certification of beef ($p<0.05$), retail outlet condition ($p<0.1$) and beef price ($p<0.01$). Based on the computed WTP, Urban beef consumers are not willing to pay a premium price -75.622 for frozen beef but rather would have to be given a discount of N76 per kg of beef for them to be willing to purchase frozen beef. For the urban beef consumers, they are willing to pay extra N85 per kg of certified beef while the rural beef consumers are willing to pay N4 per kg of certified beef. It can be concluded that both government and private sector should take advantage of the huge potential investment opportunities in the delivery of low fatty beef, certified beef and establishment of hygienic retail outlets, such as modern meat shops, especially in urban areas.

Keywords

Improved beef delivery services, Discrete choice experiment, Wiliness to pay, Mixed logit

Presenters Profile

Grace Zibah Rekwot is a Research fellow at the National Animal Production Research Institute, Ahmadu Bello University Zaria, Nigeria. She holds a bachelor's degree in Economics, an MSc and a PhD in Agricultural Economics from Ahmadu Bello University, Zaria Nigeria. She has research experience in agricultural technology adoption and livestock value chain analysis.

Introduction

Nigeria is faced with problem of low protein supply due to the widening demand-supply gap for livestock products. Beyond the quantity issue, quality is becoming a prominent issue in national discourse on livestock products. Consumers have started to attach more importance to the safety and standardization of livestock products particularly beef than ever before (Yami et al., 2017). Consumer preferences for safety and quality meat are becoming evident with important consequences for transformations in the livestock industry and meat marketing in Nigeria, but little is known about how consumers value the quality of meat (Yami et al, 2017). Yet, most consumers are unsure of the source or the hygienic condition of the beef they consume as beef retail outlets do not have any identification labels nor registration and also, beef sold to consumers do not undergo thorough inspection or supervision by the consumer food protection agencies causing risk of health hazards (Ehirim et al. 2012; Kwaghe et al. 2016). Empirical evidence on market potentials of value addition through improved safety and quality attributes of beef is limited in Nigeria. Hence, there is little evidence-based literature for upgrading beef cattle value addition. To close the gap for quality standards in beef value chain in line with the agricultural promotion policy of Nigeria, safety and quality characteristics or attributes of beef such as packaging of beef, freshness of beef, fat content of beef, certification of beef, traceability of beef (meat is traceable to abattoir), hygienic retail outlet amongst others are areas of possible value addition that can be explored based on the demand of consumers. In this paper, we seek to assess the potential market demand for improved beef marketing services in northern Nigeria, based on urban and rural beef consumers' preferences.

Methods

The study was conducted in Kaduna, Kano and Kastina States of north-west zone, Nigeria. Primary data were collected within the period of January to March 2018. We implemented a discrete choice experiment (DCE) to gain insights into beef consumers' preferences for improved beef marketing services (safety and quality attributes of beef). This was implemented among a sample of 240 beef consumers across urban and rural communities in the research area. The DCE consists of six attributes namely freshness of beef, fat content of beef, certification of beef, retail outlet condition, packaging of beef and price of beef, and the attributes had two levels with the exception of price which had six levels. The experimental design for the choice experiment was generated using NGENE statistical software. Based on the six attributes and attributes levels, the design had 18 paired choice sets that were randomly blocked into two blocks of 9 choice sets. Each choice set consists of two scenarios known as alternatives (A and B) and a baseline line (alternative A). Alternatives A and B of each choice set contains different scenarios of improved beef purchase options while alternative C also known as opt-out option is the current beef purchase scenario of consumers. To aid understanding of the choice experiment by beef consumers, the choice sets were presented in the form of visual aids known as choice cards. The analysis of the DCE data was implemented using mixed logit (MXL) model for urban and rural beef consumers.

Results

The coefficients of the alternative-specific constants (ASCs) of the estimated MXL models for both urban and rural beef consumers were negative and statistically significant at 1% probability level. This indicates that in general, the beef consumers prefer to purchase beef associated with safety and quality attributes (proposed option) over their current beef purchasing practice (business-as-usual option). Yet, we find considerable differences in preferences for the various attributes of beef between the urban and rural beef consumers. The coefficient of freshness of beef (frozen beef) for the urban beef consumers was negative and statistically significant at 1% probability level. This shows that the urban beef consumers have a negative preference for purchase of frozen beef, which implies that the beef consumers prefer purchase of fresh beef over frozen beef. A plausible reason could be due to lack of guarantee of the source of the beef when it is purchased in frozen form, among other reasons. The coefficient of fatness of beef (low fatty beef) for the urban beef consumers was positive and statistically significant at 5% probability level, which suggests that the beef consumers are more interested in purchase of beef with low fat content over beef with high fat content. This may be attributed to the growing consumer awareness on the health risk of consuming beef with high cholesterol. The coefficient of certification of beef (certified beef) for both the urban and rural beef consumers was positive and statistically significant at 5% probability level, which indicates that the beef consumers have a positive preference for certified beef as against uncertified beef. This suggests that the beef consumers are conscious of the safety of beef for human consumption. The coefficient of retail outlet condition (hygienic retail outlet) for both the urban and rural beef consumers was positive and statistically significant at 5 and 10% probability levels respectively. This indicates that the beef consumers are interested in beef purchase from hygienic retail outlets rather than the traditional open-air unhygienic retail outlets, which implies that the cleanliness of beef retail outlets matters a lot for the consumers beef purchasing behaviour. The negative and significant price coefficients at 5 and 1% probability levels of the estimated models for the urban and rural beef consumers respectively indicates that the beef consumers have negative preference for a higher beef price in line with *a priori* expectation. This is consistent with the decreasing effect of higher prices on consumers demand. The standard deviations of most of the attributes are significantly different from zero, which indicates that there is substantial heterogeneity in the beef consumers' preferences.

We estimated the willingness to pay (WTP) for beef attributes by the urban and rural beef consumers respectively. Based on the computed WTP for freshness estimated at -75.622, this implies that urban beef consumers are not willing to pay a premium price for frozen beef but rather would have to be given a discount of N75.622 per kg of beef for them to be willing to purchase frozen beef. The results also show that the urban beef consumers are willing to pay extra N 30 and N 23 per kg for low fatty beef and beef sold in hygienic retail outlet respectively. The rural beef consumers are willing to pay only N 2 per kg of beef sold in hygienic retail outlet. Overall, the WTP estimates show that the urban beef consumers value beef safety and quality attributes more than the rural beef consumers, which implies that there is a higher potential market for improved beef marketing services in urban areas compared with the rural areas. This is likely because meat consumption is more prevalent in urban centers with much higher educational status and higher income earning consumers relative to less urban or rural centers (Betru and Kawashima, 2009; Mao *et al*., 2016).

Conclusion

In general, our results point to huge potential investment opportunities in beef value chain activities to meet the demand of consumers in urban areas, especially in the delivery of certified beef amongst other desirable attributes. Our results suggest that both government and private sector should take advantage of the huge potential investment opportunities in the delivery of low fatty beef, certified beef and establishment of hygienic retail outlets, such as modern meat shops, especially in urban areas. Beyond gaining ex ante insights on consumers preferences for safety and quality attributes of beef, our study also extend the application of DCE methodology in food marketing particularly in the context of a developing country such as Nigeria.

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Analysis of Tomato production in some selected local government areas of Kano State, Nigeria

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Abstract

This study analysed tomato production in some selected Local Government Areas of Kano State, Nigeria. The specific objectives were to: describe the socio-economic characteristics of tomato farmers; assess tomato value addition by farmers and marketing channels; determine the profitability of tomato production; and identify the constraints associated with tomato production in the study area. The study adopted multistage sampling technique to collect primary data from 101 respondents using a semi-structured questionnaire. Data collected were analysed using descriptive statistics and gross margin analysis. The findings of the study reveal that tomato production is a male-dominated activity, who are mostly married (85.5%), having an average household size of 9 persons. Similarly, the study revealed that all the respondents were small-scale farmers cultivating below 5 ha of land with a mean farming experience of about 15 years. Findings of the study revealed that the majority of produce are sold at the farmgate and local markets, mostly in fresh forms. The gross margin of the venture was ₦302832, while the Net farm income and return on investment were ₦245916 and 114.5% respectively. This implies that tomato production is a profitable venture in the study area. Based on the result, pest and diseases, lack of modern production and processing facilities, inadequate capital, inadequate information on production and marketing, price fluctuation, and lack of government support were ranked topmost among the respondents' challenges. The study recommends among others the need for farmers to be encouraged to form strong cooperative societies through which they can access resources necessary for their activities.

Keywords

Gross Margin analysis, tomato, production, Kano State, Nigeria

Presenters Profile

Kola A. Adewuyi (PhD) is a senior lecturer at the Department of Agricultural Technology, Federal Polytechnic, Mubi, Adamawa State, Nigeria. His fields of interest are Statistics, Econometrics, and production economics. He has authored several papers and articles published in both local and international journals and conferences.

Introduction

The Nigerian state will continue to depend on agriculture to meet its various socio-economic needs, considering its role in the provision of food and employment for the nation's ever-increasing population. Tomato (*Lycopersicom esculentum*) is among the major vegetables being produced in the country, and is consumed in various forms (Aditi *et al*., 2011; Aremu et al., 2016). Nigeria is among the world's leading producers of tomato (ranked 16th), and also the leading producer in Sub-Saharan Africa (Ugonna et al., 2015). As at 2010, the country's production was about 1.8 million metric tonnes, which represent about 68.4% of West-African production (FAO, 2010). Despite this status in the global and regional ranking in tomato production, the country still imports tomato to meet its demands (Edeh 2017; Okojie, 2017). According to Sunday *et al.* (2018), Nigeria's annual tomato imports is valued at US$170 million. This is because tomato is highly consumed across all the regions of the country, constituting about 18% of the daily vegetable consumption of households (Babalola et al., 2010). The plant is a rich source of vitamin A and C, and also contains minerals like iron, phosphorus and is the richest source of nutrients, dietary fibres, antioxidant like lycopene and beta-carotene, the compounds that protect cells from cancer.

The plant's life span ranges between three to four months, and adapts well to different cropping systems. Tomato in Nigeria is widely cultivated in Northern parts of the country, because of the effect of seasonality (Aminu *et al*., 2007). Small-scale farmers hiving less than 5 hectares of land constitute the majority (90%) of the producers (Faostat, 2014; Sahel research, 2015). Large scale tomato production in Nigeria is mainly under irrigation during the dry season, when temperatures are mild and humidity is moderate. However, tomato production in the rainy season is usually affected by pests and diseases that are prevalent under such humid and warm conditions. According to Ugonna et al. (2015), tomato farmers just like other farmers are constrained by poor production practices due to low soil fertility, lack of improved seeds, lack of improved technology, inadequate pest and weed control, high postharvest losses and lack of processing and marketing infrastructure among others. Currently, tomato yield per hectare in Nigeria is low, estimated at an average of 20-40 tons per ha/annum, and 40-50% of the output is lost due to the poor handling, processing and preservation practices in Nigeria (Faostat, 2014). Similarly, the challenges of the farmers are being compounded by the ravaging incidence of diseases, particularly in 2016 when *Tuta Absoluta* (tomato leafminer*)* destroyed farmers' annual harvest.

In view of the nation's population, and the level of consumption of the commodity in the country, the Federal Government of Nigeria was able to develop a new tomato sector policy (Olanite 2017; Edeh 2017; AETS Consortium, 2018). The objectives of this sector policy reform were to enhance import substitution of tomato paste, stimulate investments in the national tomato processing industry and create employment, and contribute to the reduction of the huge post-harvest losses (Edeh 2017; Okojie, 2017). This policy targeted the leading locations of tomato production in the country. One of such areas where this policy was expected to stimulate positive gains was Kano State, which produces about 7.5% (44,020 Ha) of the nation's total area under tomato production (Plaisier et al., 2019). The State is located at the merge between the Central area and the Northern area and has a Sahelian climate, which is suitable for tomato production (Van der Waal, 2015). Kano State is the commercial nerve centre of the entire northern Nigeria, and also the most populous state in the country (National Population Commission, 2006).

Tomato production entails different cost out lays, hence the need to know its profitability before venturing into the production. Profit maximization is one of the important goals of farm business. This can practically be achieved through the knowledge of costing production and estimation of benefits in monetary terms hence these prompted this research work. Profitability in some businesses exists because they are managed more efficiently than others. The prospect of earning and maintaining profitability serves as the incentive for creativity and efficiency among farmers. Profitability stimulates farmers to venture into risky business and also drive them to develop ways of cutting cost and adopting new technologies, always in an effort to satisfy consumer interest (Troke, 1981). Therefore, the main objective of the study is to analyse how profitable tomato production has been in one of the leading production areas of Nigeria, which is Kano State. The specific objectives were to:

i. describe the socio-economic characteristics of tomato farmers;
ii. assess tomato value addition by farmers and marketing channels;
iii. determine the profitability of tomato production;
iv. identify the constraints associated with tomato production in the study area.

Methodology

The Study Area

Bunkure and Kibiya Local Government Areas (LGA) were selected for the study from areas of high tomato production in the State. The State is located at the merge between the Central area and the Northern area and has a Sahelian climate, which is suitable for tomato production (Van der Waal, 2015). The climate of area is the tropical dry-and-wet type. The and dry season lasts from mid-October to May, during which the mean monthly temperature is between 21 and 23^{0}C with a diurnal range of 12 to 14^{0}C. The harmattan winds prevail at this time. Similarly, the wet season lasts from June to September, the mean monthly temperature during this period is in excess of 30^{0}C and the daily range is up to 20^{0}C.

Sampling Technique

A multistage sampling technique was adopted to select respondents for the study. In the first stage, two Local Government Areas were randomly selected from the list of areas identified as notable tomato production areas by the Kano state Agricultural and Rural Development Authority (KNARDA). In the second stage, purpose sampling method was used to select five communities that are actively involved in intensive tomato production. These communities were; Bunkure town, Zango, Galadanci, Nasarawa, and Kuruma. In the third stage, simple random sampling technique was used select 101 tomato farmers for the study. Semi-structured questionnaire was used to collect primary data from the sampled respondents for the study.

Analytical Technique

Descriptive statistics and farm budgeting technique (gross margin analysis) were used to analyse the data collected for the study. Descriptive statistics, which involve the use of frequency table, mean, and percentages were used to describe the respondents' socioeconmic characteristics, value addition and marketing channels, and identify farmers constraints. Similarly, gross margin analysis was used to assess the profitability of tomato production in the area. The formulas are presented thus;

Gross margin

$GM = \sum P_i Q_i - \sum K_j X_j$ .... (1)

where:

- GM = Farm Gross Margin (₦/ha)
- P_i = Unit price of output (₦/Kg)
- O_i = Quantity of output (Kg/ha)
- K_i = Unit cost of variable input $_j$ (₦/ha)
- X_j = Quantity of variable input $_j$ (Kg/ha)
- $P_i Q_i$ = Total revenue (₦/ha)
- $K_j X_j$ = Total cost associated with variable input $_j$ (₦)
- Gross Margin = Total Revenue (TR) – Total Variable Cost (TVC)
- TR = Output (Q)* Price (P)

Net Farm Income

Net farm income (NFI) = Total Revenue (TR) – Total Cost (TC) .... (2)

Total Cost = Variable Cost (TVC) + Fixed Cost (FC)[3]

Return per Naira invested = NFI /TC

Results and Discussion

Respondent's Socio-Economic Characteristics

The distribution of the respondents' socioeconomic characteristics is presented in Table 1. The result revealed that in terms of age, the result revealed that the majority (51.5%) of the respondents were below 40 years of age. This implies that the majority of the respondents are within their economically active age and would be able to undertake the farming activities with the expected vigour. Based on gender, findings of the study revealed that tomato farming is male-dominated activity as all (100%) the respondents were of the male gender, and mostly married (85.5%). The average household size of the respondents was about nine people, implying a relatively large household size that can supply family labour for production. The distribution of the respondents' level of educational attainment indicated that the majority (79.2%) of the respondents have attended formal schools, while 20.8% had no formal education. This shows that the majority of the respondents are literate enough to understand how best the commodity can be produced using new innovations if they are exposed to them. Findings of this study further revealed that all the respondents were small-scale farmers having farm holdings of less than 5 hectares, but are mostly experienced in the activity (average farming experience of 15.3 years). In terms of access to credit, the majority (53.5%) had no access to the facility, and also most of them do not belong to any cooperative society (83.2%). The study also revealed that most of the respondents were visited by agricultural extension agents.

[3] The Total Fixed Cost (TVC) is composed of; Depreciation on Farm Implements, Cost of Rent Farm Land, and cost of Labour.

Table 1: Socioeconomic Characteristics of the Respondents (N=101)

Variable	Frequency	Percentage	Mean
Age (Years)			39.6 years
20-29	15	14.9	
30-39	37	36.6	
40-49	27	26.7	
50-59	18	17.8	
≥60	4	4.0	
Gender			
Female	0	0.0	
Male	101	100.0	
Marital Status			
Married	86	85.1	
Single	6	5.9	
Divorced	3	3.0	
Widowed	6	5.9	
Household Size			9 People
1-5	19	18.8	
6-10	42	41.6	
11-15	23	22.8	
16-20	13	12.9	
>20	4	4.0	
Educational Attainment			
No Formal Education	21	20.8	
Primary Education	27	26.7	
Mass Literacy	10	9.9	
Secondary School	17	16.8	
Tertiary Level	26	25.8	
Farming Size			0.78 Ha
<5	101	100.0	
Farming Experience			15.3 years
1-5	9	8.9	
6-10	21	20.8	
11-15	25	24.8	
16-20	21	20.8	
>20	25	24.8	
Cooperative Membership			
Member	17	16.8	
Non-Member	84	83.2	
Access to Credit			
No	54	53.5	
Yes	47	46.5	
Access to Extension Services			
No	15	14.9	
Yes	86	85.1	

Source: Field survey, 2019

Tomato Value Addition and Marketing Channels

Farmers are expected to trade agricultural commodities to earn income. Figure 1 shows the channels the respondents use to trade the commodity after harvest. Findings of the study revealed that the majority of the produce is sold at the farmgate, followed by local markets, and then to off-takers. Similarly, Figure 2 shows the value farmers add to their produce before selling them. The result revealed that transportation, packing, and storage are the most prominent activity in the area. Other activities include drying and grinding.

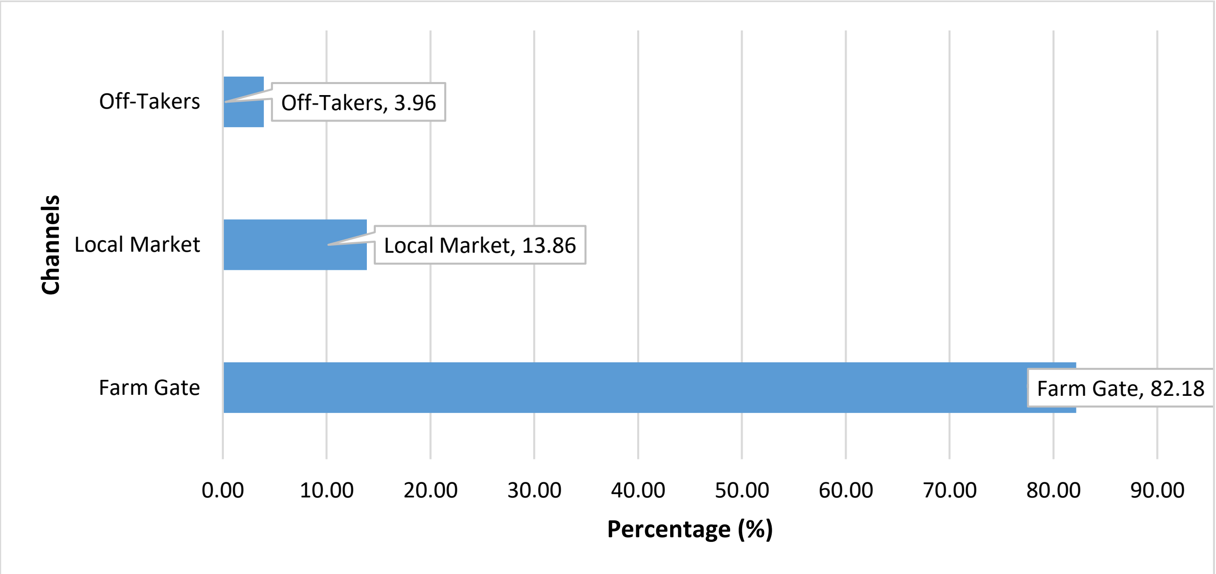

Figure 1: Tomato Marketing Channels in the Study Area

Source: Field survey, 2019

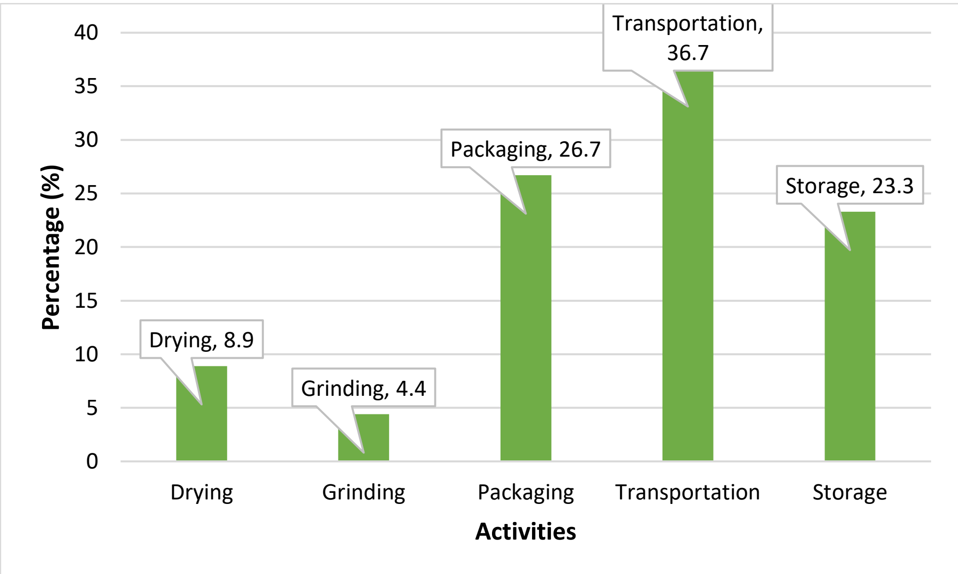

Figure 2: Value Added to Tomato by the Farmers

Source: Field survey, 2019

Profitability of Tomato Production

The profitability of tomato production was estimated using gross margin analysis as shown in Table 2. The essence of the analysis was to assess the gains made on the investment in the farm, and also identify areas that need improvement to maximize gains. The result showed that the respondents incurred the bulk of the expenses on the variable inputs of fertiliser (25.2%), fuel and watering (16.4%), pesticide/insecticide (14.4%), and ploughing (7.9%). Similarly, rent on land was the highest fixed cost component, and constituted about 21% of the total production cost. The gross margin of the venture was ₦302832, while the Net farm income and return on investment were ₦245916 and 114.5% respectively. This implies that tomato production is a profitable venture in the study area.

Table 2: Average Cost and Return of Tomato Production

Variable	Value [4](₦/Ha)	Percentage (%)
A. Variable Cost Components		
i. Clearing	3595	1.7
ii. Ploughing	17020	7.9
iii. Planting	2148	1.0
iv. Fuel and watering	35303	16.4
v. Manure	1799	0.8
vi. Inorganic Fertiliser	54148	25.2
vii. Weeding	3872	1.8
viii. Stalking	1148	0.5
ix. Pesticides/Insecticide	30883	14.4
x. Harvest	5536	2.6
xi. Bagging/Sorting	2400	1.1
Total Variable Cost (TVC)	***157852***	***73.5***
B. Fixed Cost		
i. Depreciation on Farm Implements	1895	0.9
ii. Cost of Rent Farm Land	45000	21.0
iii. Labour	1021	4.7
Total Fixed Cost (TFC)	***56916***	***26.5***
Total Cost (TVC + TFC)	**214768**	**100.0**
C. Returns		
Sales	425349	
Household Consumption/ Gifts	35336	
Total Revenue (TR)	**460684**	
Gross Margin (GM)	302832	
Net farm income (NFI)	245916	
Return on investment (ROI)	114.5(**%**)	

Source*:* Field survey, 2019

Constraints Associated with Tomato Production

The result in Figure 3 outlines the various constraints faced by tomato farmers in the study area. Based on the result, pest and diseases, lack of modern production and processing facilities, inadequate capital, inadequate information on production and marketing, price fluctuation, and lack of government support were ranked topmost among the respondents' challenges. Other challenges included conflicts/insecurity, high perishability of the produce, high cost of processing, and poor tomato varieties being cultivated. The interplay of these

[4]$1USD= ₦365 (Naira) as at the time of conducting the survey

myriad of challenges has limited the ability of the farmers to maximise gains from tomato production in the area.

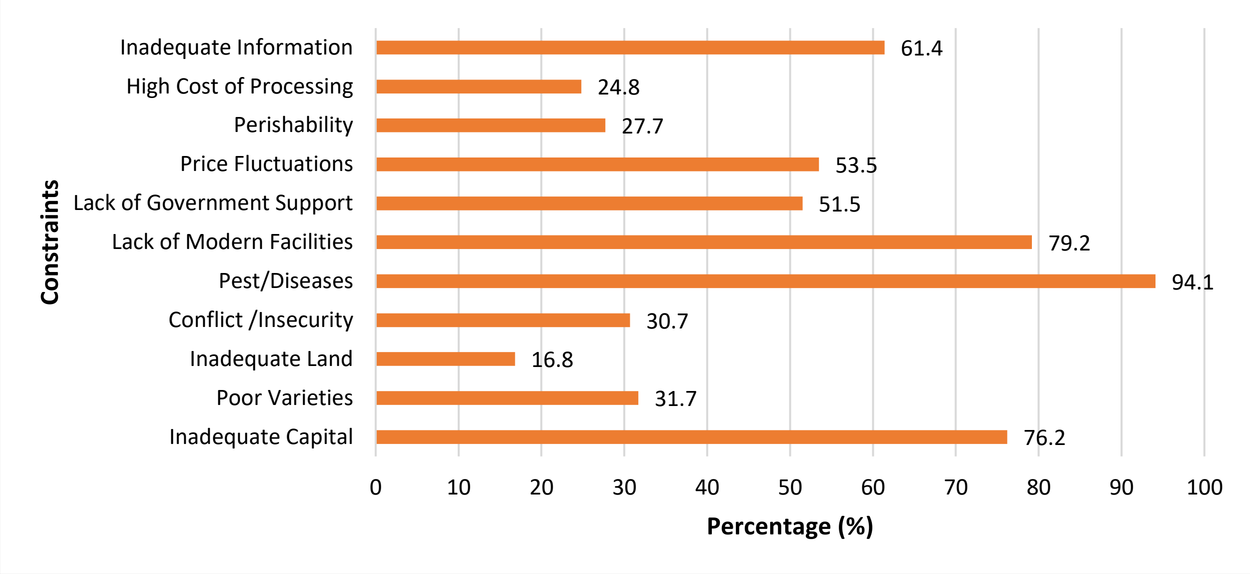

Figure 3: Constraints Associated with Tomato Production

Source*:* Field survey, 2019

Conclusions and Recommendations

This study has established that tomato production is a profitable venture in the study area, however, if necessary actions are taken by key stakeholders in the sector, particularly by the government, farmers will be able to maximise gains and improve their wellbeing. Based on the study, the following recommendations were made to increase the profitability of tomato production:

i. There is the need for farmers to be encouraged to form strong cooperative societies through which they can be able to access resources necessary for their activities.

ii. The government should assist farmers with training and resources that they can use to prevent/control pest and diseases which usually reduce their profitability.

iii. Financial institutions should be encouraged to give farmers enhanced access to credit facilities as groups or individuals so as to enable them afford the adoption of improved farming technologies that can boost production.

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Does adoption of organic fertilizer improve households' welfare? A case study of Farm Households' in Nigeria

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Abstract

Using nationally representative agricultural households' data from the 2018/2019 General Household Survey in Nigeria, this study examined the welfare impact of the adoption of organic fertilizers, a form of conservation agriculture. We employed Propensity Score Matching and Endogenous Treatment Regression model to assess the impact and adjust for biases in estimates. The Impact analysis using PSM showed that adopters of conservation agriculture were 22% and 26.4% better than non-adopters based on the per capita house expenditure and per capita food expenditure outcomes. Estimations from the linear endogenous treatment regression model which accounts for unobservable differences revealed a positive and significant impact of the adoption of organic fertilizers on farm household welfare. The determinants of adoption revealed that access to extension services and poor soil status are common determinants of the adoption of organic fertilizers.

Keywords

Organic fertilizer, Welfare Impact, Conservation Agriculture

Presenters Profile

Zainab Oyetunde-Usman is a Commonwealth Scholar and a Ph.D. Candidate at the Natural Resources Institute, University of Greenwich. Her research focuses on impact assessment of improved maize varieties and choice modelling of preferences for drought-tolerant maize varieties in Northern Nigeria. She has published papers in recognised journals and has contributed to several conferences. Her research interest includes agricultural technology adoption, impact assessment, food and market economics, food security, poverty alleviation, and behavioural economics.

Introduction

Conservation Agriculture (CA) has evolved as an agricultural innovation that involves practices such as the use of organic fertilizers, minimum tillage, permanent organic soil cover, and crop rotation. In recent years, most of these practices were modelled under the Climate Smart Agriculture technological innovations been promoted in most developing countries to sustainably increase agricultural productivity and incomes, adapt and building resilience to climate change, and reducing and/or removing greenhouse gases emissions, where possible FAO (2013). Across sub-Saharan Africa, these practices have recorded success stories in promoting sustainable agricultural intensification and technology (Arslan et al. 2014, it directly impacts productivity and a typical solution to land and soil degradation (Giller et al. 2009). These practices have proven significant in improving productivity, food security, and income through adaptation and resilience to climate change (FAO, 2010). Despite the recorded impact of conservation agriculture on household productivity and welfare, low adoption persists as stated in various literary contexts in sub-Saharan Africa.

In Nigeria, the agricultural zones are quite a diverse spanning from the mangrove and rainforest in the Southern Areas to lower dense and scantily drought-prone agricultural zones in the Northern areas. This likely poses the country's agricultural zones to both extreme flooding and drought events. As a result of low and erratic rainfall, farm households are prone to low productivity which directly impacts their welfare and food security status. The use of conservation agriculture in Nigeria has been an age-long practice however involving primitive and use of mechanical methods of soil management at a subsistence level. Although these practices have minimally sustained productivity, they have not been able to hugely curb the issues of soil and land degradation which may be due to poor adoption of modified conservation practices. In this study, it becomes important to assess farm households' determinants of adoption of conservation agriculture and impact on welfare.

Methods

This study employs a nationally representative dataset obtained from the Nigeria General Household Survey conducted in 2018/2019 as part of the World Bank Living Standard Measurement Survey Integrated Surveys on Agriculture (LSMS-ISA) project. This project supports the redesign and implementation of the General Household Survey and serves as a larger part of the regional project in sub-Saharan Africa. For Nigeria, it was carried out in partnership between the Nigeria Bureau of Statistics, the Federal Ministry of Agriculture and Rural Development (FMA&RD), the National Food Reserve Agency (NFRA), the Bill and Melinda Gates Foundation (BMGF) and the World Bank (WB). The key objectives include (i) to improve the production of household-level agriculture statistics linked with non-agriculture dimensions of household welfare and behaviour and (ii) to foster the dissemination and use of these data. This study adopts 2795 agricultural households. The conservation practices considered are the use of organic fertilizers which include the use of manure, mulching techniques, and composting. The study also incorporated socio-economic, institutional, demographic, topographical, and regional variables including outcome variables such as per capita household expenditure and per capita food expenditure to assess determinants and impact of the adoption of CA.

The econometric model employed includes logistics regression to assess the determinant of adoption of organic fertilizers. For welfare impact, this study employs propensity score matching (PSM) based on the selection on observables to assess the average treatment effects and the average treatment effect on treated. The endogenous treatment regression model was also considered to fill in the limitation of the PSM model which is not accounting for unobservable factors that may be impacting the adoption of CA.

Results & Discussion

To assess the welfare impact of the adoption of organic fertilizers, two components of household welfare proxies were estimated for robust analysis, this includes per capita total house expenditure and per capita food expenditure. For the PSM model, the nearest2 neighbour matching method (NNM) was adopted. The NNM result showed a positive and significant impact on the adoption of organic fertilizers. The Average Treatment Effect on Treated (ATT) of the adopters of organic fertilizers on per capita total house expenditure was NGN20,500.72. This was 22% increase in welfare compared to non-adopters. Similarly, the ATT of adoption of organic fertilizers on per capita food expenditure was NGN18952.26, which was 26.4% increase in the welfare of adopters of organic fertilizers compared to non-adopters. This indicates that the adoption of organic fertilizer is significantly increased farm household welfare.

Since PSM assesses impact based on observables, biases from unobservable differences have not been controlled and could give rise to overestimation or underestimation of welfare impact. The linear regression with the endogenous treatment effect model is employed to fill in this gap. The ATE and ATT from this analysis further confirms that adopters of organic fertilizers positively and significantly impacts household welfare.

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Can low-cost soil improvement technologies deliver substantial productivity gains? Evidence from northern Nigeria

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Abstract

Increased agricultural productivity usually comes from effective application of crop and site-specific improved practices. Maize is a common cereal cultivated and consumed in Nigeria and it requires a high fertilizer input which in most cases not affordable in its inorganic form by smallholder farmers. However, smallholders have not ascertained the productivity and welfare benefits in the adoption of a low-cost soil improvement technology. In this paper, we analyze the impact of animal manure as a low-cost soil conservation practice on maize productivity in northern Nigeria. We use data from two rounds of a farm-household panel survey among maize-based farming households and estimate econometric models, including fixed effects regression model, and we performed robustness checks using pooled ordinary least squares (OLS) and random effects models. Specifically, we tested the hypothesis that the adoption of animal manure as a conservation practice does not have significant effect on maize productivity. Results showed that application of organic manure was positive, significant (at 10 percent), and have 7 percent marginal effect on maize productivity. Findings suggest a holistic approach involving the combination of low-cost soil conservation measures with external inputs such as mineral fertilizer and improved seeds. However, well-concerted policy measures and public interventions need to be in place to address the market imperfections that limits the use of high-cost inputs including mineral fertilizer.

Keywords

Soil conservation practices; animal manure; fixed-effects regression; random effects; panel data

Presenters Profile

Tolulope E. Oladimeji is a lecturer and researcher at the Division of Agricultural College, Ahmadu Bello University Zaria, Nigeria, and is currently a PhD student at the same University. His academic background is in agricultural economics and extension, where he obtained a bachelor's degree from Federal University of Technology Akure, Nigeria. He equally has a master's degree in agricultural economics from Ahmadu Bello University, Zaria Nigeria. He has research experience in production economics, conservation agriculture and food security.

Introduction

Soil fertility depletion is considered one of the main biophysical limiting factors for increasing per capita food production for smallholder farmers in sub-Saharan (SSA) countries in general (ten Berge et al., 2019), and Nigeria in particular (Oyinbo et al., 2019). One often cited constraint that acts as a barrier to the adoption of costly productivity-enhancing technologies such as inorganic fertilizer by smallholder farmers is cash constraint (Lambrecht et al., 2014; Liverpool-Tasie et al., 2017; Tambo and Mockshell, 2018). Given this context, smallholder farmers often resort to the use of low-cost soil conservation inputs (e.g. organic manure) with limited use of inorganic fertilizer (Liverpool-Tasie et al., 2017; Martey, 2018). Yet, it remains unclear whether the adoption of such low-cost, low-risk soil conservation measures without a corresponding investment in high-cost, high-risk inputs (e.g. inorganic fertilizer, improved seed varieties, etc.) can produce substantial productivity and welfare gains for smallholder farmers. Although, integrated soil fertility management (ISFM) involves the use of both the high- and low-cost inputs with inorganic fertilizer as a vital entry point, the causal effects of the low-cost soil conservation inputs have not been adequately addressed. Previous empirical studies (such as Teklewold et al., 2013; Tsegaye et al., 2016; Liverpool-Tasie et al., 2017) focus on the causal effects of inorganic fertilizer and/or improved seeds. Despite the agronomic potentials of soil conservation inputs and their low-cost and low-risk appeal to smallholders, empirical findings on whether and to what extent they contribute to productivity is rather limited in the agricultural technology adoption and impact literature. In this paper, we analyse the impact of a low-cost soil conservation input, animal manure on maize productivity in northern Nigeria.

Methods

The study was conducted in the maize belt of northern Nigeria. We use a two-year panel survey dataset of 792 maize-producing households. The first round of survey was in 2016 and the second round was in 2017. The survey instrument had plot-, household- and community-level components, with modules on household demographics, land ownership, social capital, credit, extension, crop management, etc. We used a fixed effects regression model as the primary estimation strategy, and we performed robustness checks using pooled ordinary least squares (OLS) and random effects regression models.

Results

The summary statistics show that the average age of the farmers was about 44 years, with average farming experience of 19 years. The average household size was about 9 persons, and each household owns livestock equivalent to 2.14 tropical livestock units. The average farm size was about 3.11 hectares, with an average focal maize area of 0.82 hectares. On average, 76% of the farmers applied manure on their maize plots in 2016 cropping season. In 2017, the share of farmers who applied manure decreased to 69%, which suggests that there is temporal variability in the use of manure among the maize farmers in the study area. Overall, the use of manure is relatively high in the study despite the variability between the two years. This is likely because it is a low-cost, low-risk input in comparison with inorganic fertilizer, and some farmers rely on it as a substitute or complement to inorganic fertilizer (Liverpool-Tasie et al., 2017). The results of the fixed effects regression show that the application of manure has a positive and significant effect on maize yield at the 10% significance level. In addition, the observed yield increasing effect is 7%, which is relatively small. This suggests that the adoption of low-cost soil conservation inputs, such as manure is unlikely to boost productivity without the use of complementary external inputs such as inorganic fertilizer, improved seeds, etc. Our results are robust to the use of alternative models, including pooled OLS and random effects regression models. Overall, the positive effect that we find is consistent with the findings of previous studies in other SSA countries (e.g. Martey, 2018 in Ghana).

Discussion

The fixed effect regression result showed that adoption of organic manure was found to have positive and significant effect on maize yield. Specifically, manure as a low cost conservation practice marginally increased the probability of enhanced maize production by 7%. Apparently, the positive and significant effect is attributed to the agronomic potentials of animal manure towards building soil organic matter, microbial functioning and chemical properties of the soil with subsequent long term effect on the soil (Martey, 2018). It is noteworthy that the relatively low marginal effect of 7% on maize yield is as a result of independent adoption rather than as a package with other low cost conservation practices. A wide-spread misconception by many smallholder farmers is that fertilizers from organic source such as animal manure, even though cost-ineffective to purchase, transport and applied, it has high-moisture and low-nutrient contents (Timsina, 2018), thereby attributing to relatively low effect on maize yield. In general, we find limited effect of the adoption of manure on maize yields. This finding suggests that animal manure could likely have a larger impact if adopted as a package with other low-cost soil conservation measures (e.g. intercropping, crop rotation, etc.) and external inputs (e.g. inorganic fertilizer, improved seeds, etc.). Thus, a more holistic approach that involves the use of external inputs, such as mineral fertilizer and improved seeds in combination with the low-cost soil conservation measures – the concept of ISFM is potentially more promising in producing substantial productivity gains. However, this will require further research to evaluate the impacts of such holistic approach. In addition, well-concerted policy measures and public interventions need to be put in place to address the market imperfections that limits the use of high-cost inputs including mineral fertilizer and improved seeds.

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Does gender of farmers affect commercialisation and profitability of arable crop production in Nigeria?

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Extended Abstract

Introduction

Agricultural market participation is the integration of subsistence farmers into the input and output markets of agricultural products with a view of increasing their income level, hence reducing poverty (Holloway and Ehui 2002). Barrett (2008) sees market participation as both a cause and a consequence, and provides households the opportunity to benefit from trade. That is, they can sell their surpluses and purchase goods and services they need, according to their comparative advantage. Nevertheless, markets frequently fail to serve the interest of the poor, especially women, hence a need for the understanding of market participation which is critical for designing poverty eradication schemes. Women are known to be twice as likely as men to be more involved in agriculture related activities (Odame et al, 2002). Despite improvement in building women's capacities in Nigeria, gender gap in entitlements, assets acquisition and resource control continue to persist (Akinsanmi, 2005). This "gender gap" hinders women's' productivity and reduces their contribution to the agricultural sector and to the achievement of broader economic and social development goals (FAO, 2012). For several years, government and development agencies have given top priority to gender issues in agricultural development planning and policies with the motive of facilitating an increase in the level of female gender involvement in the different value chains of agricultural commodities with greater emphasis on commercialization (FAO, 2008). Closing the gender gap in agriculture would produce significant gains for society by increasing agricultural productivity, reducing poverty and hunger and promoting economic growth. Therefore, the study aims at examining the effect of gender on commercialization of arable crop production in Nigeria.

Methodology

The study area is Nigeria, West Africa. Secondary data employed for the analysis were obtained from General Household Survey (GHS) and Living Standards Measurement Study (LSMS) 2015/2016 data collected by National Bureau of Statistic (NBS). These data contain the information of 2,487 arable crop-farming households. Descriptive statistics are used to determine the socio-economic characteristics of the farmers and Market Participation Index (MPI), to estimate the level of arable crop commercialization among the farming households. In addition, Gross Margin (GM) analysis was adopted to determine how profitable the arable crop production is. Lastly, Tobit Regression model was used to examine the effect of gender on commercialization of arable crop production in Nigeria.

Results

Our results revealed that female farmers are on average older (61.58 years) compared to their male counterparts (52.86 years). The household size of male to female-headed households are nine and five respectively, while almost 70% of both genders have no access to credit. Land available for cultivation to male farmers is 1.32 hectares, which is four times higher than that of the female farmers. The major arable crops cultivated by the farmers are cassava, maize, yam, beans, sorghum and millet. The annual value of arable crops production by male famers (N243,417.50/US$628.24) is much higher than that of the female (N94,664.44/US$244.32), while the value of sales is N78,414.85 (US$202.38) and N27,680.54 (US$71.44) for both male and female farmers, respectively. Likewise, male arable crop farmers recoded higher profit (N156,840.50/US$404.79) than the females (N52,296.25/US$134.97).

Although the value of arable crops produced and sold by male farmers is higher than the female, the results showed that female farmers recorded relatively higher commercialization index (0.285) than their male counterpart (0.283). The Tobit Regression result elucidates that access to extension service, increased farm land and income are significant commercialization promoting factors. However, farmers in the northeast of the country participated the least in agricultural markets. This may not be unconnected to the incidence of Boko-haram attack witnessed within this region.

Conclusions

Based on the findings, female farmers have higher levels of agricultural commercialization than the males. This asserts that for improved agricultural commercialization to be achieved in Nigeria, female farmers should have equal access to physical and productive assets as men. This could be achieved through reform of land use act, which will favour female farmers in acquiring farmland. In addition, Income enhancing policy measures, probably in the form of subsidy provision and credit access, should be an option for low income earning arable crop farmers in order to increase their level of participation in the market and profitability.

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Presenters Profile

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Keynote Presentation: Modelling biodiversity: Determinants of threatened species

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Abstract

This study uses nonparametric quantile and partial regressions to model a number of threatened species (reptiles, mammals, fish, birds, trees, plants) in relation to various economic and environmental variables (GDPc, CO¬2 emissions, agricultural production, energy intensity, protected areas, population and income inequality) for a sample of 71 countries. From the analysis and due to high asymmetric distribution of the dependent variables it seems that a linear regression is not adequate and cannot capture properly the dimension of the threatened species. We find that using OLS instead of non-parametric techniques over- or under-estimates the parameters which may have serious policy implications.

Presenters profile

George Halkos is a Professor in Economics of Natural Resources. He holds a Master of Sciences (M.Sc) in Project Analysis, Finance and Investment and a Doctorate of Philosophy (D.Phil) in Cost-Benefit Analysis with the use of Mathematical Models and Game Theory and with application to Environmental Economics from the Economics Department of the University of York (England). He has worked as team leader and research fellow in various research and academic institutions as the University of Piraeus, the Athens University of Economics (former ASOEE), the University of the Aegean, the Stockholm Environment Institute, the Panteion University, the ATEI, etc. for research projects financed by the European Union (PHARE programs), the Hellenic Republic Ministry of Development, the National Statistical Service of Greece, the EUROSTAT, the Ministry of Employment. He is the Director of the Operations Research Laboratory. He was Associate Editor in the journal Environment and Development Economics (Cambridge University Press) for the last six years. His research interests are in the fields of Applied Statistics and Econometrics, Simulations of Economic Modelling, Natural Resource and Environmental Economics, Applied Micro-economic with emphasis in Welfare Economics, Air Pollution, Game Theory, Mathematical Models (Non-Linear Programming).

Towards better understanding of structural changes in EU agriculture: the index decomposition approach

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Abstract

Over the last couple decades, the agricultural sector in the European Union has faced significant structural transformations. This study is aiming at developing a novel index decomposition analysis framework that allows decomposing the changes in the average farm size into three explanatory indicators. The proposed model investigates the change in the average farm size using the indicator of the 'pure' farm size change and two structural indicators that explain the changes in farming types and the spatial distribution within the EU.

According to the previous research, there is no agreement on the definition of the farm size. For this reason, the study applies three different measures of the farm size: the average utilised agricultural area, the average standard output, and the average labour force directly employed. The proposed model employs the multiplicative Logarithmic mean Divisia index I method in order to monitor the dynamics of the average farm size. Each measure of the farm size is decomposed individually. The empirical study relies on Eurostat data and covers the period from 2005 to 2016. The results demonstrate three levels of aggregation: the EU, 28 Member States, and 7 farming types.

Results suggest that the development of the average farm size depends on the selected measure. Over the period 2005–2016, the highest farm size growth at the EU level was recorded for standard output and utilised agricultural area per farm, while the change of labour force directly employed on farm was modest. It should be noted that the estimated change for the average standard output at the EU level was remarkably higher than for the average utilised agricultural area. At the EU level, the main driving force of change in the average farm size was the increase of the 'pure' farm size indicators, while the contributions of two structural indicators were less significant.

The decomposition of the average utilised agricultural area showed the most significant growth of farm size on general field cropping, specialist cereals, oilseed, and protein crops farms (farming type I) and specialist dairying, cattle-rearing and fattening, cattle-dairying, rearing and fattening, sheep, goats, other farms (farming type III), while the farm size of mixed livestock, mainly grazing livestock and mainly granivores farms (farming type VI) declined. Over the period 2005–2016, the largest increase in the average utilised agricultural area took place in France, the United Kingdom, Spain, Germany, and Poland.

The decomposition of the average standard output demonstrated the greatest increase of farm size on general field cropping, specialist cereals, oilseed, and protein crops farms (farming type I), specialist dairying, cattle-rearing and fattening, cattle-dairying, rearing and fattening, sheep, goats, other farms (farming type III), specialist pigs and poultry farms (farming type IV), while the farm size of mixed livestock, mainly grazing livestock and mainly granivores farms (farming type VI) decreased. The countries with the highest increase in the average standard output were France, Italy, Germany, Poland, and Spain.

The decomposition of the average labour force directly employed on farm showed the modest increase in farm size for the farming types I and III, while the employment on specialist pigs and poultry farms (farming type IV), mixed cropping farms (farming type V), mixed livestock, mainly grazing livestock and mainly granivores farms (farming type VI), field crops-grazing livestock combined, various crops and livestock combined farms (farming type VII) decreased. Over the period from 2005 to 2016, the dominant share of Member States demonstrated a stable or slightly decreased farm size.

To conclude, the proposed model could be a useful tool mapping changes in the agricultural system after important events (for example, changes in legislation, post-crisis behaviour). Although findings suggest that the change in the average farm size at the EU level was driven by the pure increase in the average farm size, results also demonstrate that structural indicators have evolved too. However, the role of structural indicators depends on the measure of the farm size and varies across types of farming and the Member States.

Keywords

Agriculture, Index decomposition analysis, Farm size, Structural change

Presenters Profile

Nelė Jurkėnaitė is a Senior Researcher at the Lithuanian Institute of Agrarian Economics. In 2010, she became a PhD graduate in Social Sciences (Management and Administration) at Vilnius Gediminas Technical University. She is recently involved in research and experimental development projects covering the following topics: price transmission, structural changes in agriculture, agricultural waste in circle economy. The main research areas: agricultural policy, farm viability, price transmission, and supply chains.

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Examining the Drivers of Dairy Farm Productivity Growth

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Abstract

Using data from the Northern Ireland Farm Business Survey for the time period from 2005 to 2016, this study provides answer to the question of what drives dairy farm productivity growth. The following are the main findings emanating from our analysis: first, the dairy sector experienced moderate productivity growth in terms of efficiency in the use of inputs to produce output. Second, sector productivity growth has been largely driven by on-farm technological progress while resource allocation between farms appeared to have a negative effect. Finally, the results also show that the main drivers of farm-level productivity include: farm size, milk yield, stocking density, capital to labour ratio, share of hired labour, purchased feed per cow, labour input per cow, and share of direct payment in farm output. Our findings provide useful insights for policymakers seeking to further improve productivity at sector - and farm- level.

Keywords

Total factor productivity, Northern Ireland, Dairy farms

Presenters Profile

Kehinde Oluseyi Olagunju is an Agricultural Economist at AFBI Office Newforge Lane, Belfast. His research focuses on using econometric techniques in analysing agricultural systems to inform policy directions. Recent research projects conducted for the Department of Agriculture, Environment and Rural Affairs (DAERA) include investigating the impact of Common Agricultural Policy reforms on Farm production and Land Rental Prices to provide policy support for the design and implementation of future reforms of agricultural subsidies in the post-BREXIT era. He is member of the Agricultural Economics Society (AES), International Association of Agricultural Economists (IAAE), and OECD Network for Farm-Level Analysis among other professional bodies.

Introduction

The dairy sector is one of the most important agricultural industries in Northern Ireland (NI). In 2018, the sector accounted for approximately 10% of total active farms, and contributed the largest share (32%) of total agricultural gross output in NI, a larger share than any other agricultural sector (DAERA, 2018). The NI dairy sector is significant to agriculture in the United Kingdom (UK) as well, contributing approximately 15% of the total dairy output in 2015/2016, second only to England's share (AHDB, 2016).

Despite the importance of this sector, it is still faced with a number of important challenges, including limitations to factors of production such as land and labour. Another pressure on the industry is that successive policy reforms of the Common Agricultural Policy (CAP) and World Trade Organisation (WTO) agreements have increased the exposure of domestic producers to world markets. The NI dairy sector may face even greater international competition as the UK negotiates Free Trade Deals across the globe in the post-Brexit era. Besides, there is a growing concern in recent years about the future performance of the sector in the face of falling farmgate milk prices and increasing input costs (AHDB, 2016). Against this backdrop, it is important to gain a better understanding of the sector's performance to maintain and improve competitiveness in a changing national and international context. One approach is to benchmark the competitiveness of NI's dairy sector compared to other competing regions, such as England and Wales, Netherlands, and Estonia. A key indicator of competitiveness is productivity: a measure of how efficiently inputs are converted to outputs.

The productivity of NI agriculture as a whole is currently measured using aggregate data, however, it is not disaggregated into individual sectors, so it is difficult to determine trends in dairy productivity specifically. The objective of this study is to gain an improved understanding of the patterns, and factors impacting the productivity of NI dairy. This is accomplished by combining two complementary analyses.

Computation of an aggregate dairy sector productivity measure

Measuring aggregate productivity enables trends to be examined over time and allows for comparison with national productivity indices using similar coverage and methods. Having access to an index that is already widely applied by national agricultural ministries provides information on the competitiveness of the NI sector compared to other regions. This is useful for developing government policy to support productivity by learning from more productive dairy sectors. If there are differences in policy approaches, then there may be an opportunity to adopt some of the more successful approaches within NI.

Regression analysis of farm-level productivity, farm and farmer characteristics

Analysis of the marginal impact (positive or negative) of different factors at farm level identifies the drivers of productivity and provides evidence for policy to tackle productivity constraints. Econometric analysis is a useful tool for exploring the links between productivity and farm-specific characteristics and choices.

Methods

To compute a measure of productivity at aggregate level for the dairy sector, a total factor productivity (TFP) index was developed using a non-parametric approach called the Fisher Index. The TFP was first computed at farm level using the adjusted Fisher index using the Eltetö Köves Szulc (EKS) formula (Elteto and Koves, 1964). TFP is expressed as an index relative to a specific 'base' farm and year. For any farm-year observation, this measure gives the relative difference in TFP between that and the base observation. The TFP obtained here is at farm-level, therefore, to aggregate the farm-level inputs and outputs in sector-level TFP requires the application of specific sample weights. Sample weights are applied ex-ante to aggregate output and input at the sector level to measure the TFP of the dairy farm sector.

To examine the factors influencing farm-level productivity of specialised dairy farms a panel fixed effect regression model was used. The data are obtained from the NI Farm Business Survey (FBS) for the period 2005 -2016.

Results

The results reveal that the dairy sector has experienced moderate productivity growth each year between 2005 and 2016 with a sector-level TFP growing at 0.5% a year. This growth indicates a slight improvement in the efficiency with which inputs are used to produce milk and other dairy products. Estimates also show that the annual growth rate of output increased by 4.6% and that of inputs increased by 4.2% implying that the annual growth rate of output marginally outpaced the growth of input. This suggests that the moderate productivity growth in NI dairy sector is driven by output growth, with inputs also increasing over the period but not at the same pace with outputs.

Our estimates from the econometric analysis using the fixed panel approach shows that the farm-level TFP is significantly affected by farm management and socioeconomic factors, investment and technology choice, and agricultural subsidies.

Factors that positively and significantly influence farm-level TFP include herd size, milk yield, stocking density, share of hired labour, college and University education variables, while factors such as intensity of purchased feed input, labour intensity per cow, share of direct payments in farm output are negative and significantly affect TFP level of dairy farms. The results related to the interaction effect between age and education variable (age and agricultural college attainment) is positive suggesting that dairy farms with younger farmers that have attained at least agricultural college qualification tend to have greater productivity.

Our estimates also show that net investment and capital to labour ratio variables negatively impacted productivity. However, when these variables were lagged by 3-years, the relationship between investment and productivity turned positive. When lagged net investment interacts with education, the results show that education has a complementary effect on net investment by increasing the positive effect of long term net investment on productivity. Finally, as expected, being located in less-favoured areas is associated with lower TFP, implying that natural conditions could be a constraint for productivity growth.

Discussion

Our results show that the sector experienced moderate growth in productivity (0.5% a year) between 2005 and 2016. This slight improvement in productivity has been driven by output growth, with inputs also increasing over the period but not at the same pace as outputs. This implies that the expansion in output from dairy farms, primarily milk, relative to input used was the main driving force of productivity growth.

The estimation of the factors influencing productivity show that herd size and stocking density have a positive impact on productivity, but purchased feed input per cow tends to have a negative impact. This result is consistent with the interpretation that purchased feeds may be increased to drive yields in the short-term in response to prices, but that there is a diminishing return (there is a greater impact on profit for the first few units of extra feed with less and less of a benefit as more feed is used). The analysis also shows that more productive farms have a lower intensity of labour input per cow. These results suggest that policy strategies aimed at efficient management of inputs are key for NI dairy farms to become more productive. This may involve optimising labour input as part of the labour, capital and land resource mix. For example, adoption of zero-grazing systems in larger herds could be an effective management option.

Also, the results show that college and University education variables have a positive impact on productivity, suggesting that additional years in education, including specialist agricultural training, have a positive impact on farm management performance. Finally, our results show that capital investment is a significant factor in improving productivity, although this impact may be delayed. The findings echo the relevance of providing support for dairy farmers to invest in equipment and machinery that will help realise improvements in efficiency and overall competitiveness and sustainability of the sector. In addition, our findings also highlight the role of education in the relationship between investment in innovative technology and productivity. The findings reveal that innovative dairy technologies require a sufficient level of complementary education to trigger an increase in productivity at farm level.

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Farm Mechanization and Potential role of Robotics in Malawi

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Abstract

Malawi's agricultural economy comprises of the smallholder subsector on communal land, and the leasehold and freehold estate subsectors. Large farms and estates use modern inputs more frequently, than the smallholder farmers. Jayne (2016) reported the ratio of cultivated land area to total land holding size declines as farm size increases.

This paper highlights farm mechanization and the potential for role of robots in Malawi. We provide a global overview of the situation in Africa and in Malawi. We also highlight the potential role of robotics. Farm mechanization often follows various stages, starting from the use of mechanical power for power-intensive operations that require little control to increased use of mechanically powered technologies, and finally to automation of production. Past state-led mechanization in Africa often failed due to insufficient understanding of the nature of demand for mechanization technologies among farmers and insufficient knowledge of private-sector functions.

There are dedicated mechanization committees and departments as well as a decentralized approach to mechanization and a clear commitment to mechanization along the value chain in Malawi. While the Ministry of Agriculture, Irrigation and Water Development (MoAIWD) is responsible for maintaining Government-owned facilities with tractor and draught animals for hire, the private sector is expected to lead this intervention area.

Malawi is not on track for meeting the Malabo Commitment area number 3.1. This relates to access to agriculture inputs and technologies. However, according to the selection methodology the country is part of a cluster of countries indicating rapid mechanization rates. Malawi has had an average annual machinery growth rate of 2.7% and a high agricultural output growth of over 6%. Malawi has made strides to introduce automated farming such as use of central pivot system of irrigation. However, information on how this is performing is rather limited.

Keywords

Mechanization, Robotics, Agriculture, Malawi

Presenters Profile

Mr. Kumwenda is a seasoned economist with vast experience in programme/ project development, evaluation of projects and programmes and undertaking business studies. Mr. Kumwenda has extensive experience in policy formulation and policy analysis, general micro economic analysis using various programs such as excel, SPSS and STATA. He holds a Master of Science Degree in Agricultural Economics from the University of Aberdeen in UK, Bachelor of Science Degree in Agriculture from Bunda College of Agriculture, University of Malawi. He also has certificates in Agricultural Policy Analysis and Cooperative Development. He has published over 20 publications in form of papers and reports. He has attended a number of short courses, workshops and seminars at national and international fora. He is a member of the International Association of Agricultural Economists and a member of the Economic Association of Malawi (ECAMA).

Introduction

Malawi's dual agricultural economy comprises of the smallholder subsector on communal land, and the leasehold and freehold estate subsectors. There are still about 2.6 million farmers on 3.3 million hectares under customary land. The estate subsector was mostly created after independence in 1964 with a million hectares converted from customary land into leasehold and transferred to commercial farmers, the government created the estate subsector. Reliable current land-size distribution data do not exist, since the latest agricultural census was in 2006.

Recent studies suggest that large farm sizes are often not associated with higher production and productivity. While larger farms and estates use modern inputs more frequently, the ratio of cultivated land area to total land holding size declines as farm size increases (Jayne, Chamberlin, Traub, & Sitko, 2016). Only 15 percent of land owned by estates was cultivated in 2006 (Xinshen, Cossar, Housou, & Kolavali, 2014). Except for sunflower and tea, data also shows that yields by smallholders were above those of estates.

Farm mechanization often follows various stages, starting from the use of mechanical power for power-intensive operations that require little control to increased use of mechanically powered technologies, and finally to automation of production. The level, appropriate choice and subsequent proper use of mechanized inputs in agriculture have a direct and significant effect on production, profitability, sustainability, the environment and on the quality of life of people engaged in agriculture. Human power, animal power and the use of machines are the three main options for farm production.

Human, animal and machine power complement each other in the same household, farm or village, the choice being determined by local circumstances. Ultimately, farm mechanization aims to enhance overall productivity and production at the lowest cost.

This paper highlights farm mechanization and the potential for robots in Malawi. First, we present definitions and concepts. Then we provide a global overview and the situation in Africa. Next we make an over view of the case for Malawi. We then highlight the potential role of robotics and make conclusions and recommendations.

Methods

The methods used were desk reviews and case studies at different levels including: Global; Sub-Saharan and Malawi. We provide concepts and definitions that guide mechanization and robotics as outlined below.

Definitions and Concepts

Mechanization

There are several definitions of farm mechanization. Starkey (1998) defined farm mechanization as the development and introduction of mechanized assistance of all forms and at any level of sophistication in agricultural production to improve efficiency of human time and labour. Rogers (1995) on the other hand described mechanization as a decision to make full use of innovation or technology as the best course of action. In general, farm mechanization implies the use of tractor, power tiller, land levellers, weeder, sprayer, sprinkler, electric pump set, diesel pump set, harvester, thresher etc.

The Food and Agriculture Organization of the United Nations (FAO) defines mechanization as "the application of tools, implements and machinery in order to achieve agricultural production" as cited by Clarke (1997). These can all be operated by manual, animal, or engine (fossil fuel or electric) power. Essentially, agricultural mechanization represents technological change through the adoption of nonhuman sources of power to undertake agricultural operations. Mechanized agricultural operations can be grouped into power- and control-intensive functions Mechanization of power-intensive agricultural operations, such as land preparation, threshing, grinding, and milling, is characterized by nonhuman sources of energy input to replace human and animal ones required in the operations. On the other hand, mechanized control-intensive operations, such as planting, weeding, winnowing, and fruit harvesting, require greater human judgment and mental input in addition to energy (Pingali 2007).

Robotics and Automation

Mechanization refers to the replacement of human power with mechanization power of some form. The use of hand power tools is not an example of mechanization. Automation and mechanization are often confused with each other: mechanization saves the use of human muscles whereas automation saves the use of human judgment. Mechanization displaces physical labour, whereas Automation displaces mental labour as well.

Mechanization affects one or two industries at a time. Automation is the replacement of human thinking with computers and machines. Automation creates jobs for skilled workers at the cost of unskilled and semi-skilled workers. It affects many industries at the same time.

There are several theories that are used to guide analytical framework for advancing mechanization efforts.

Analytical Framework

Several theories have been developed that guide the analysis of farm mechanization. For example, Boserup's (1965) and Ruthenberg's (1980) theory of agricultural intensification.

Agricultural intensification is defined as the increased application of labour and other inputs per unit of land (intensified use of inputs) and more frequent cropping of land through reducing fallow periods (intensified use of land). However, in agricultural economics literature that does not focus on the long-term evolution of farming systems, agricultural intensification is exclusively referred to as the intensified use of inputs, while the intensified use of land, that often leads to the expansion of cropping areas by reducing forest or fallow land, is referred to as agricultural extensification (Tachibana, Nguyen, and Otsuka 2001).

Boserup (1965) (who later further formalized and tested by Pingali, Bigot, and Binswanger 1987; Binswanger and McIntire 1987; and McIntire, Bourzat, and Pingali 1992) links agricultural intensification with increased demand for agricultural products. Such increased demand is the result of population growth and improved market access, including both domestic and international market access (which expands agricultural demand beyond farmers' own subsistence needs).

Hayami and Ruttan's (1970, 1985) advanced the induced innovation theory. According to this framework, agricultural intensification is driven by increased population pressure and rising demand for agricultural products. This in turn prompts mechanization, both through the adoption of existing and the development of new technologies. Essentially, we can expect mechanization to be adopted by farmers when the appropriate conditions arise, and it would not be profitable in the absence of such conditions.

Although these theories exist and appear to be applicable to Malawi, we have not come across studies that have been used to provide empirical evidence in the context of Malawi. Next, we explore case studies at Global, African and Malawi levels.

Global Overview

Mechanization and Robotics

The mechanization of farming practices throughout the world has revolutionized food production, enabling it to maintain pace with population growth except in some less-developed countries, most notably in Africa. Agricultural mechanization has involved the partial or full replacement of human energy and animal-powered equipment (e.g. ploughs, seeders and harvesters) by engine-driven equipment. Most of this is tractor driven and to a lesser extent self-propelled equipment (including harvesters, sprayers, fertilizer applicators, planters and seeders). Agricultural mechanization has been pioneered in North America and Europe and more recently in Japan, and is now spreading rapidly throughout the world. Notwithstanding such progress, a significant element of human and animal powered mechanization remains, particularly in the poorer regions of the world. The importance of enhancing and upgrading such mechanization practices prior to the almost inevitable transition to engine-driven equipment is now well recognized.

Automation of agricultural mechanization is an intensive area of research and development with emphasis on enhancement of food quality, preservation of operator comfort and safety, precision application of agrochemicals, energy conservation and environmental control. Automation applications will be orientated towards and assist in the attainment of environmentally friendly and sustainable systems of agricultural and food production.

However, the difficulties in matching environmental concerns and sustainability with an ever-increasing world population cannot be underestimated, especially in the developing countries. Thus, there may be a tension between maximizing food production on the one hand and implementing sustainable development and environmental protection systems (e.g. erosion control) especially, in poorer regions, where the demand for increased food production follows logically from an increasing population.

Sub-Saharan Africa

Mechanization and Robotics

Directly or indirectly, agriculture forms the basis of the livelihood of a large majority of the population in sub-Saharan Africa (SSA). The smallholders comprising the larger part of the rural population usually plough, weed, harvest and transport their crops manually. Similar conditions apply in downstream sectors, ranging from processing and transport to marketing, particularly from field to primary market. Agricultural mechanisation can help to improve this situation. Its significance is demonstrated in the declaration contained in the African Union's "Agenda 2063: The Africa We Want" to abolish the mattock by 2025. This is at the very core of a more systematic agricultural modernization strategy. If implemented sensibly and gradually for particularly appropriate processes and in the case of labour shortages, a frequent criticism associated with this approach, namely that mechanisation causes job losses, does not necessarily apply. Indeed, the job ratio created via mechanisation can be thoroughly positive. However, a number of aspects must be taken into account in order to ensure agricultural mechanisation is successful.

Diao et al (2016) highlight that African agriculture still relies predominantly on human muscle power despite anecdotal evidence on urbanization and rising rural wages, in contrast to other developing regions that have experienced rapid increases in agricultural mechanization during the past few decades. Past state-led mechanization pushes in Africa often failed due to insufficient understanding of the nature of demand for mechanization technologies among farmers and insufficient knowledge of private-sector functions. It suggests that private-sector-driven supply models are better positioned to meet this demand than direct government involvement and certain types of subsidized programs.

While mechanization levels in North Africa are on par with those in Asia and Latin America, humans are the main power source for agricultural production in Africa south of the Sahara, although there are different estimates of the exact levels of mechanization. Until recently, sustained adoption of agricultural mechanization, through engine-powered machinery and animal traction, has been limited to a few areas in Africa south of the Sahara, much of which has been on large-scale commercial farms. While there was a major push toward agricultural mechanization by African governments during past decades, these largely failed due to lack of demand among farmers (Pingali, Bigot, and Binswanger 1987). In the aftermath of the failure of state-led mechanization, farm power availability declined in Africa during the 1980s and 1990s, while it grew rapidly throughout other developing regions (Mrema et al. 2008).

Nevertheless, demand for mechanization may have begun to emerge in some parts of Africa in recent years, prompting a renewed focus on mechanization. Where demand for mechanization has existed, private supply chains have formed around it in a number of cases, providing machines and equipment, hiring services, and repair services. Although they may be quite responsive to farmers' demand, private supply chains are not always fully developed, often due to crowding out/distortion caused by government policies and programs, the high fixed investments required, or other market failures that need to be overcome through additional support.

This emphasizes the importance of establishing an appropriate and supportive policy framework to enable private supply channels to effectively meet demand. However, there is still a paucity of research and knowledge about mechanization demand, the current extent of mechanization, and its effects on production, labour, and other outcomes.

Overview of Mechanization and Robotics in Malawi

Malawi remains locked in that time with nearly 85% of the population surviving on small family plots through the use of a single garden hoe. While this type of cultivation somewhat accomplished its goals when the population was 4 million people in the early 1960's, today's population of over 18 million people must have more than a hand hoe to survive. One step at a time the Malawi Project is helping the people of Malawi to create more successful methods for food production and storage. Here are some of the ways it is working.

Drip irrigation

One of the major ways to offset famine in Malawi is to use some sort of irrigation that can offer the opportunity to plant an entire crop during the dry season when there is no rain for as much as 6 months. The use of drip irrigation not only offers hope when there is no rain, it also reduces by a full 25% the amount of water that needs to be used to irrigate growing crops while in the long run, there will be environmental issues that will be considered. Over 11,000 drip irrigation lines have been sent to the country and, along with training, have been distributed to all three regions of the country.

V-tractors

In an attempt to create some degree of mechanization the Malawi Project has worked closely with Agricultural Aid International to develop a small, easy-to-learn, and easy-to-use farm tractor that can fit the needs of small village areas where the use of powered equipment is new to the population and slow to make inroads into the culture. Six of the V-Tractors have been sent to Malawi, and have distributed to test areas in all three regions of the country.

Walk behind tractors.

The walk behind tractor is another creation of Agricultural Aid International and is meant to handle village needs where the larger tractor is prohibited by cost and fuel usage restrictions. The walk behind holds similar traits to the roto-tiller designed units that handle yard work, and small family gardens in the United States, Canada, and Europe. Three of the walk behind tractors have been sent to Malawi, one of them to the prison system to assist in food production for the inmates.

Grain storage facilities.

Dubbed the Joseph Projects, two test sites have brought into being large community storage buildings, whereby local churches, or community development groups work together as a farm co-op to raise sufficient crops to store for the community against future poor crop production years. The co-operating communities raise additional crops, and then form community programs to distribute the food in times of need.

Central pivot system.

The system is a mechanized irrigation system type which irrigates crops in a circular pattern around a central pivot. It consists of a radial pipe supported by towers that pivot around a central point. Along the radial pipe, nozzles are equally spaced. As it rotates, water is released from the nozzles and irrigates crops. The system is also water saving as it ensures spot application of water required for irrigation. Centre pivots come in different sizes, however their layout in the field is actually dependent upon the layout of the field considering issues like shape and obstructions. So it is not easy to generally predict the number that might be required on a field. The device works automatically and maintenance is low, hence almost non-existent labour costs. The disadvantage, however, is that the initial cost of irrigation pivot centre may be considerable compared to other types of systems. This system is largely used at Dwangwa and Nchalo sugar estates in Malawi.

According to Malabo Montpellier Panel (2018), Malawi is not on track for meeting the Malabo Commitment area Number 3.1. Its score of 3.9 out of 5.53, according to the 2018 Biennial Review Report by the African Union, reflects the low mechanization level in the country. The overall commitment category score is 10. However, according to the selection methodology, the country is part of a cluster of countries indicating rapid mechanization rates. Malawi has had an average annual machinery growth rate of 2.7% and a high agricultural output growth of over 6%.

Policy and Investment Framework

Mechanisation reduces hard labour, relieves labour shortages, improves productivity and timeliness of operations, and contributes to climate adaptation. Malawi developed its National Agriculture Policy (NAP) in 2010 and its National Agricultural Investment Plan (NAIP) Ministry of Agriculture and Food Security, Republic of Malawi, 2010. The Agriculture Sector Wide Approach (ASWAp) highlights the Malawi's prioritised and harmonised agricultural development Agenda. (Ministry of Agriculture and Food Security, 2010)

The National Agriculture Policy recognizes that the majority Malawian farmers continue to use rudimentary pieces of farm equipment such as hoes, while much of the harvesting and processing of farm output is done by hand. NAP aims to:

- Promote mechanisation of farming, agro-processing and value addition;
- Facilitate market-based imports of new and used agricultural machinery that are appropriate for Malawi and meet established standards;
- Facilitate market-based imports and production of quality spare parts of agricultural machinery;
- Facilitate the growth of entrepreneurs in the agricultural mechanisation and services industry;
- Promote home-grown inventions and innovations in agricultural mechanisation and service provision; and
- Promote the development and growth of farmer-managed agricultural mechanisation groups.

NAIP aims at increasing the use of machinery in farming and agro-processing activities by 50%. This will be achieved in full harmony with environmental considerations, including the full integration of conservation agriculture principles. It highlights the importance of mechanization. This is highly inefficient and burdens millions of households, making agriculture unattractive, particularly to the youth. Mechanisation is, therefore, a crucial input for crop production that has been underdeveloped and underfinanced in Malawi. Mechanisation is an often-overlooked climate change adaptation measure that, in concert with other activities, can improve the resilience of the farming sector.

The government has secured lines of credit for US$10 million for irrigation and US$40 million for mechanization from the Indian government, and for setting up a sugar processing plant in Salima district. In order to meet all targets, the country has yet to make marked strides in extension services' reorganization and the promotion of agribusiness and cooperatives. Despite these efforts, the allocation of resources for mechanization is very minimal as outlined in Figure 1, only 3.7% was allocated to mechanization by development partners.

Institutional Framework

While MoAIWD is responsible for maintaining Government-owned facilities with tractor and draught animals for hire, the private sector is expected to lead this intervention area. Many of the private stakeholders are farmers themselves, through their farmer organisations (Tea, tobacco and sugar).

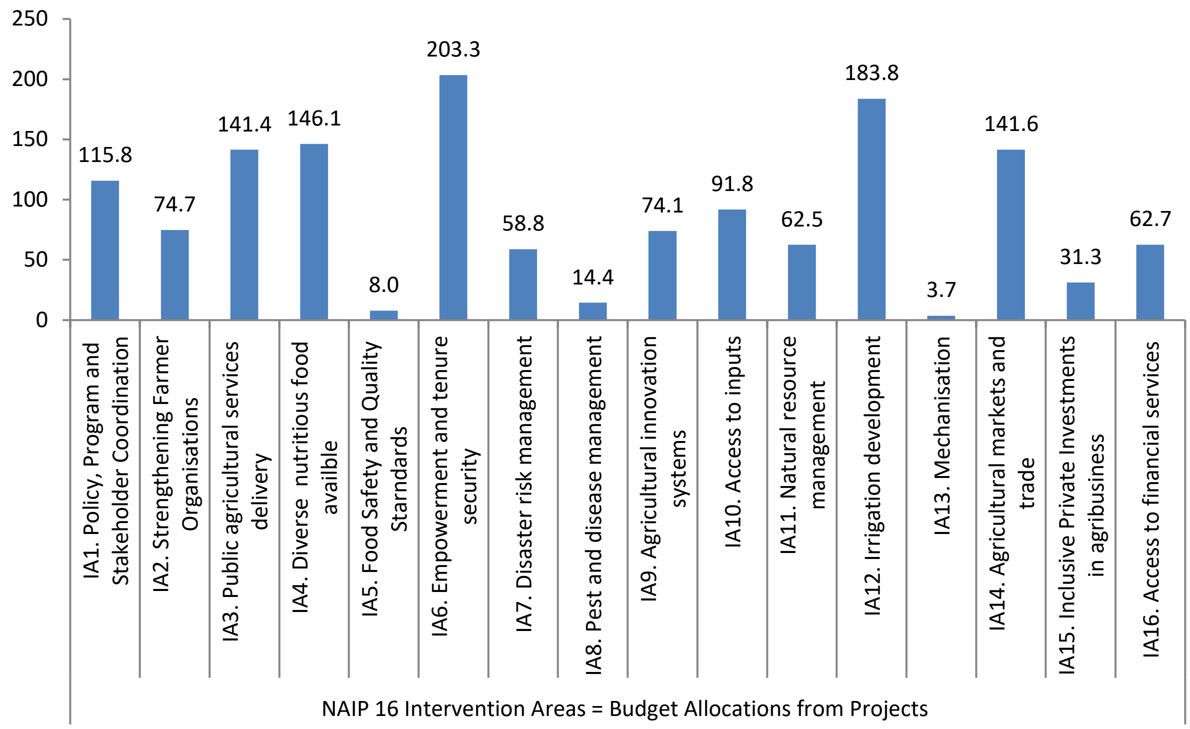

Figure 1: Funding to NAIP Intervention Areas by the Development Partners

Source: Ministry of Agriculture, Irrigation and Water Development Agriculture Sector Performance Report 2019.

There are dedicated mechanization committees and departments, as well as a decentralized approach to mechanization and a clear commitment to mechanization along the value chain. The Malawi Growth and Development Strategy has been shown to be effective in advancing the uptake of mechanization along the value chain. However, as the recent Biennial Review Report has shown, progress remains to be made to meet national and international targets, including the Malabo commitment of ending hunger by 2025.

The MoAIWD seeks to promote agricultural productivity and sustainable management of land resources to achieve food security and increased incomes and ensure sustainable growth. The ministry is organized into seven technical departments, including the Crops Development Department, which was created to facilitate producers' access to improved and locally appropriate crop production and agro-processing technologies. The department is responsible for the implementation of farm mechanization programs. Specifically, it offers training to extension agents and farmer groups in crop production technologies and in post-harvest management of crops, including agro-processing. The department is split into six sections, one of them dedicated to "Farm Mechanization." In its function to promote new technologies, the Crops Development Department also works closely with the Agricultural Technology Clearing Committee (ATCC), which releases new production and processing technologies, such as fruit juice extracting machine coordinates and undertakes   Agricultural research

The Department of Agricultural Research Services (DARS) locate at three main research stations as well as sub-stations strategically positioned throughout the country. Much of this work is undertaken in collaboration with CGIAR institutions of which there are normally 4-5 active in the country at any time. Universities also play an important role in agricultural research and human resource development. In the tobacco sector the Agricultural Research and Extension Trust is responsible for conducting research and providing technical and extension services.

In addition to the public hiring services, private companies also offer supplies of agricultural equipment. CAMCO Equipment Limited has been operating in Malawi since 2000, supplies agricultural machinery and implements along the value chain, including walking tractors, disc ploughs, harrows, planters, harvesters, trailers, water pumps, sprayers, food processing equipment, harvest machines, and smaller farming tools. Besides affordable prices, CAMCO offers a wide range of products, after-sales services, and spare parts. The company has established 32 distributers and agents in Malawi.

Targets

The NAP, (which is) supposedly implemented within the NAIP, builds on various policy statements to improve agriculture productivity against national, regional, and global opportunities and challenges. The NAIP is based on priorities, (which were) also stressed as major key areas the Malawi Growth and Development Strategy (MGDS, III). Regarding mechanization, NAP emphasizes the following in a clear investment strategy.

- Increase the number of hectares under tractor-hire schemes from 2,090 hectares (2009/2010) to 10,000 hectares in 2013/2014, with total investments of US$10 million;
- Increase the number of hectares under oxenization, from 1,100 hectares to 16,615 hectares in 2013/2015;
- Increase the distribution of hand planks from 1,200 to 60,000 in 2013/2014; and
- Conduct review meetings on farm mechanization and oxenization efficiency in agriculture.

Progress on these targets is not well documented and therefore hard to trace how much has been achieved, except for the Malabo declaration that highlights some of the general achievements as presented in this paper.

Key Findings

This paper has highlighted the various efforts that aim to mechanize the agricultural sector and the potential for robotics. Throughout the world, farm mechanization has revolutionized food production, enabling it to maintain pace with population growth except in some less developed countries, notably in sub-Saharan Malawi is lagging behind in using mechanization and robotics. There are bottlenecks that need to be addressed in order to move to the next stages of mechanization.

Farm mechanization often follows various stages, starting from the use of mechanical power for power-intensive operations that require little control to increased use of mechanically powered technologies, and finally to automation of production. We have provided a global overview of the situation in Africa and in Malawi. The review provides evidence of the different stages.

The National Agriculture Policy and the National Investment Programme recognize that the majority Malawian farmers continue to use rudimentary pieces of farm equipment such as hoes, while much of the harvesting and processing of farm output is done by hand. There are dedicated mechanization committees and departments as well as a decentralized approach to mechanization and a clear commitment to mechanization along the value chain.

Discussions and Recommendations.

The agricultural industry in Malawi may grow as a mix of small, creative start-ups and partly in partnership with established international corporations. The private sector can play a crucial role bringing to scale the design, development, and provision of technologies that have proven impactful. Increased cooperation between the private sector and research institutions is needed to strengthen domestic mechanization efforts by developing locally appropriate and affordable machines and technologies.

Substantial investments in public-private partnerships must be made to foster research and development, vocational training, and skills development programs and to stimulate innovation along the value chain. This needs to include the design and manufacturing of equipment and the servicing of machinery and tools. For example, through mechanization service centres and technical extension services, including the collective action of farmer organizations.

The following recommended options for advancing mechanization and robotics:

- Policy, Investment Regulatory framework that recognizes the advances in mechanisation and automation. These aspects should be clearly articulated in the framework.
- Develop institutional and capacity of all categories of stakeholders
- Facilitate market-based imports of new and used agricultural machinery that are appropriate for Malawi and meet established standards;
- Facilitate market-based imports and production of quality spare parts of agricultural machinery;
- Facilitate the growth of entrepreneurs in the agricultural mechanisation and services industry;
- Develop specific strategies and interventions for small scale, medium scale and large scale farmers due to their difference in land sizes, socio-economic status and political landscape.

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The Economic Feasibility of Autonomous Equipment for Biopesticide Application

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Abstract

Since the European Union (EU) ban on neonicotinoid seed treatments in 2013, Cabbage Stem Flea Beetle (CSFB) is a pest with no effective control in the UK and the area sown to OSR has been cut in half. Biopesticides offer one promising approach, but most biopesticides have little residual effect, and consequently must be applied frequently. For a bulk commodity crop like OSR, the margins are tight and the cost of frequent application may make the crop unprofitable. Autonomous equipment could reduce application costs. If farmers own the equipment, the main cost of autonomous application is the original purchase of the machines, the marginal cost of additional applications is small. The objective of this study is to determine under what circumstances use of autonomous equipment for application of biopesticides would be profitable for farmers. The main hypothesis is that biopesticide application with autonomous equipment would be more profitable on farms that already use autonomous equipment for other field operations than on farms with conventional mechanisation. The study adapts the Hands Free Hectare (HFH) farm linear programming model by updating OSR yields and production practices for current CSFB challenges, adding alternative break crops like field beans and linseed, and includes biopesticide application with conventional or autonomous equipment. Initial results suggest that a low cost biopesticide might be profitable for farmers with either conventional or autonomous equipment, the cost of the biopesticide product is a key constraint, and HFH type retrofitted autonomous equipment still requires too much human labour. This study will be of interest to pest management researchers, agri-tech economists, OSR producers, and entrepreneurs developing autonomous farm equipment businesses.

Keywords

biopesticides, oilseed rape, cabbage stem flea beetle, autonomous equipment, robot, profit

Presenters Profile

Prof. James Lowenberg-DeBoer holds the Elizabeth Creak Chair in Agri-Tech Applied Economics at Harper Adams University (HAU), Newport, Shropshire, UK. He is responsible for economics in the Hands Free Farm (HFF) team at HAU. He is also president of the International Society of Precision Agriculture (ISPA) and co-editor of the journal *Precision Agriculture*. His research focuses on the economics of agricultural technology, especially precision agriculture and crop robotics. Lowenberg-DeBoer's research and outreach is founded in hands-on experience in agriculture, including production of maize and soybeans in NW Iowa in the USA.

Introduction

In recent decades oilseed rape (OSR) has been the most profitable "break crop" in many arable rotations in the United Kingdom, but farmers are being forced to seek alternatives because of Cabbage Stem Flea Beetle (CSFB - *Psylliodes chrysocephala*). Since the European Union (EU) ban on neonicotinoid seed treatments in 2013, CSFB has become a pest for which there is no effective conventional insecticide control and the area sown to OSR in the UK has been cut in half. Biopesticide products offer one promising approach with which to control CSFB, but most biopesticides have little residual effect, and consequently must be applied frequently. For a bulk commodity crop like OSR, the margins are tight and the cost of frequent application may make the crop unprofitable. Autonomous equipment could reduce application costs. For example, if farmers own the equipment then the marginal cost of autonomous application is small. The objective of this study is to determine under what circumstances use of autonomous equipment for application of biopesticides would be profitable for farmers. The main hypothesis is that biopesticide application with autonomous equipment would be more profitable on farms that already use autonomous equipment for other field operations than on farms using conventional mechanisation. The study adapts the Hands Free Hectare (HFH) farm linear programming model by updating OSR yields and production practices for current CSFB challenges, adding alternative break crops like field beans and linseed, and includes biopesticide applications with conventional or autonomous equipment. This study will be of interest to pest management researchers, agri-tech economists, OSR producers, and entrepreneurs developing autonomous farm equipment businesses.

OSR was a minor crop in the UK until plant breeding in the 1970s created OSR varieties that were low in both erucic acid and glucosinolates, which allow greater use of OSR oil for cooking and OSR meal for animal feed (Canola Council of Canada, undated). High erucic acid in cooking oil can lead to heart health problems. Glucosinolates create palatability and nutritional problems from OSR meal used in animal feed. Until the late 1970s, OSR oil was mainly used as an industrial lubricant and the meal was a minor livestock feed ingredient. In the late 1960s, harvested OSR area in the UK was a few thousand hectares annually (FAOSTAT, 2020). That rose to 755,717 ha by 2012. Approximately 361,000 ha of OSR are expected to be harvested in the UK in 2020 (AHDB, 2020).

Chandler et al. (2011) define biopesticides as mass-produced agents manufactured from living microorganisms or natural products and sold for the control of plant pests. Biopesticide products typically fall into one of three types according to the active substance: (i) microorganisms, such as bacteria, fungi, viruses and protozoa (this group is often extended to include some species of nematode); (ii) biochemicals, such as secondary metabolites produced by plants and micro-organisms; and (iii) semiochemicals, which are defined as chemical signals produced by one organism that causes a behavioural change in an individual of the same or a different species. Biopesticides that target insect pests currently account for approximately one fifth of all products currently registered for professional use in the UK. These product registrations are, however, almost exclusively for use on high value horticultural crops and are priced accordingly (e.g. £100-£300/ha per application) for these markets. The cost of using biopesticides is further increased by the fact that most of these products have little or no residual effect and consequently must be applied repeatedly during the period in which the crop is vulnerable to a particular pest. While biopesticides can often be applied using conventional spray equipment, applications typically require large volumes of water (e.g. up to 1500 L/ha) in order to achieve the good crop coverage required to optimise the efficacy of these products. In addition, environmental conditions at the time of application may also be an important factor in determining the efficacy of these products. This may mean that applications must be made during periods when rain is not forecast or that the application is made in the evening when humidity is higher and UV radiation is lower. To date there has been comparatively little research investigating the potential of biopesticides for the management of insect pests affecting most arable crops. The product price, the frequency of application and the volume of water applied all would create obstacles to application in broadacre crops.

Several terms are used to describe farm machines that are mobile and have some autonomy (e.g. robot, autonomous machine, automated equipment). Based on the arguments in Kyrakopoulos and Loizou (2006) for this study the word “Robot” is reserved for machines with substantial decision-making capacity, while “autonomous equipment (or machines)” is used when the technology has autonomy of operation with a predetermined path or itinerary. This study focuses on levels 4 and 5 of the widely used driving automation level scale (SAE, 2018). It should be noted that this definition, the popular terms “milking robot” and “industrial robot” are largely honorific because those machines are not mobile, and often have minimal decision-making capacity.

Autonomous equipment for crop production is being trialled throughout Europe, mainly for mechanical weeding of vegetable crops and sugar beets. The only European country with quantitative data on crop robotics and autonomous equipment is France, with over 100 autonomous machines in use in crop production (Digital Agriculture Observatory, 2018). In the USA 3% of agricultural input dealers report using robots in their businesses (Erickson and Lowenberg-DeBoer, 2020). Several companies are preparing to market retrofit kits that would convert conventional farm equipment for autonomous use. For example, the Smart Ag company in the USA is marketing a hardware and software kit that converts a conventional tractor and chaser bin for autonomous use (SmartAg, 2020).

Publicly available economic analysis of crop robotics and autonomous equipment is rare. This is because commercial farm experience with this technology is limited and many crop robot/autonomous machine technologies are in the prototype or beta test stages protected by non-disclosure agreements. Lowenberg-DeBoer et al. (2019) found 18 published studies of the economics of crop robotics all of which find that the current robotics technology is potentially profitable for producers in certain circumstances. Most of those studies use partial budgeting to examine the potential profitability of automation of a single crop operation (e.g. weeding, harvesting). The most systematic analyses are for grains and oilseeds because those technologies present fewer engineering challenges and are closer to commercialisation than robotics for horticulture. Shockley et al. (2019) employed farm linear programming to analyse the economics of using autonomous equipment for maize and soybean production in Kentucky USA based on experience with robot prototypes. The analysis suggested that relatively small autonomous equipment would have economic advantages for a wide range of farm sizes, but especially for small farms. With the availability of data from HFH and using linear programming to model a UK arable farm, Lowenberg-DeBoer et al. (2019) went beyond Shockley et al. (2019) to show that the economic benefits of robotic technology potentially go beyond labour saving to include changes in economies of scale, reduction in investment required for farm, and environmental benefits. No study on the economics of use of autonomous equipment or robotics for biopesticide application is available.

Given the urgency of the OSR pest management issues and the lack of economic analysis of autonomous equipment for pesticide application, the objective of this study is to determine under what circumstances use of autonomous equipment for application of biopesticides would be profitable for farmers. The main hypothesis is that biopesticide application with autonomous equipment would be more profitable on farms that already use autonomous equipment for other field operations than it would be on farms with conventional mechanisation. Other pesticide application hypotheses were not tested because they seem less likely to be profitable. For example, in the UK contractors typically charge £12-£16/ha for pesticide application (ABC, 2019). With repeated applications the cost would quickly outstrip any benefit. Some researchers have envisioned a small, light autonomous sprayer for targeted micro application of synthetic pesticides (e.g. a few drops of herbicide on a weed leaf). Given the volume of water recommended for many biopesticides, a substantial machine is needed just to transport the required volume of spray mixture. A small, light, cheap autonomous sprayer is unlikely for this type of biopesticide.

Methods

The hypothesis was tested using the Hands Free Hectare linear programming (HFH-LP) model of an arable farm in the English West Midlands. The HFH-LP model was based on a well tested and particularly flexible system for modelling farming operations known as the Purdue Crop/ Livestock Linear Program (PC/LP) (Preckel *et al.*, 1992; Dobbins *et al.*, 1990; Dobbins *et al.*, 1992; Dobbins *et al.*, 1994). This system was used from the mid-1990s through to 2010 as an analytical tool for Purdue's Top Crop Farmer Workshop. Farmers from across the Midwestern United States came to Purdue University each summer and developed linear programming models for their farms to evaluate alternative technologies and resource investments. Many of those farmers attributed their subsequent success in part to insights gained from the PC/LP analysis. The model has also been used in Brazil, Colombia, Thailand and several African countries. An updated version of the PC/LP system has been developed in the General Algebraic Modelling System (GAMS, 2019) modelling language (Preckel et al., 2019). The HFH-LP model is a modified version of the PC/LP model using the GAMS, software. In many ways the HFH-LP is similar to the Audsley (1981) UK farm LP, but takes advantage of more recent software.

The HFH-LP model can be expressed in the standard summation notation used by Boehlje and Eidman (1982) as:

$$Max\ \Pi = \sum_{j=1}^{n} c_j X_j \quad (1)$$

subject to:

$$\sum_{j=1}^{n} a_{ij} X_j \leq b_i \text{ for } i = 1 \ldots m \quad (2)$$

$$X_j \geq 0 \text{ for } j = 1 \ldots n \quad (3)$$

where:
X_j = the level of the *j*th production process or activity,
c_j = the per unit return (gross margin) to fix resources (b_i's) for the *j*th activity,
a_{ij} = the amount of the *i*th resource required per unit of the *j*th activity
b_i = the amount of the *i*th resource available.

The gross margin (c_j's) is total crop sales revenue minus total direct costs, and can be considered returns to fixed costs. In other words, net returns from the operation equals gross margin minus fixed costs excluding any government subsidies. In the HFH-LP analysis, the objective function was to maximize gross margin for each set of land, operator labour, and equipment. Fixed costs are land, farm facilities, equipment, and compensation for management, risk taking, and labour provided by the operator.

To focus on the essentials the initial HFH-LP is specified with a straightforward crop rotation and using standard cost estimates from the Nix Pocketbook (Redman, 2018) and The Agricultural Budgeting & Costing Book (Agro Business Consultants, 2018). The initial HFH-LP focused on the short term (two year) autumn sown winter wheat-OSR rotation which was for many UK farmers the most profitable arable cropping option in recent decades. That rotation was modelled with a range of timeliness of planting and harvesting with associated yield differences. A similar short-term, spring barley-autumn OSR, rotation was modelled with several timeliness alternatives. The barley-OSR rotations were included to give the model some flexibility in the timing of field operations. Field operation timing is drawn from Finch *et al.* (2014) and Outsider's Guide (1999). Equipment timeliness estimates and other machine relationships are from Witney (1988). All crops are assumed to be direct drill. Additional information on the HFH-LP model is available in Lowenberg-DeBoer et al. (2019).

The production costs, output prices, yields and human and machine work times from the HFH economic analysis were used. To avoid the complications of scale issues, the initial focus of the biopesticide application analysis was on a 500 ha farm with 450 ha arable. Equipment investment and cost estimates were updated with new information from the set-up of Hands Free Farm (www.handsfree.farm) on cost of a small combine (£28,000 compared to £20,000 in the initial analysis) and retrofitting non-hydrostatic drive equipment for autonomous use (£23,262 compared to £4,850 in the initial analysis). Previous research identified an equipment set with a 300 hp tractor and a trailed 36 m boom sprayer with a 3000-5000 L tank as profit maximizing for this 500 ha farm (Lowenberg-DeBoer et al. 2019). The optimal equipment set for the autonomous farm was three autonomous units each with a 38 hp tractor and associated equipment. The sprayer for the autonomous unit was a trailed 4 m boom and 200 L tank. Especially important for this analysis is the assumption that this is a farm on which there is one operator and that operator is available 100% of their work time for farm work. This means that the main cash cost of additional biopesticide applications is the biopesticide product. Temporary labour can be hired on a daily basis if needed.

The HFH-LP model was adapted in three ways: 1) including the impact of the neonicotinoid ban on CSFB damage to OSR in the short rotations, 2) introducing a longer rotation including other break-crops and 3) developing a winter wheat-OSR short rotation with biopesticides for CSFB control. Based on the research literature, CSFB damage to OSR is modelled both through land sown to OSR that is abandoned (and resown to another crop in the spring) and yield loss on the OSR harvested. CSFB damage as measured in research studies varies widely geographically and from year to year (Alves et al. 2015; Hughes et al. 2015 & 2017; Nicholls 2015 & 2016; Scott and Bilsburrow 2015 & 2017; White 2015; White and Cowlrick 2016; Wynn et al 2014 & 2017). There is not enough research to allow estimation of reliable average OSR abandonment or OSR yield loss. Consequently, this study used the 5% of OSR area abandoned and 10% yield loss as representative loss levels.

One alternative to the two year cereal/OSR rotation is a longer rotation including additional non-cereal break crops (EPPO, 2017; Bell, undated). The focus is on non-cereal break-crops because of the substantial yield penalty for second and subsequent year cereal production. That longer rotation can still include OSR if the overall presence of OSR in the agricultural landscape is reduced enough to break the CSFB cycle. For this study a six year rotation with winter wheat every other year, with the break crops being OSR, field bean, and linseed. The field bean and linseed can be either autumn or spring sown. Parameters for this longer rotation are taken from standard UK farm budgeting references (e.g. ABC, 2019; Finch et al, 2014; Redman, 2019). It is assumed for the model that the OSR in this rotation is not damaged significantly by the CSFB. If it is found that CSFB continues to damage OSR even in the longer rotation, OSR could be dropped entirely from that rotation. Without high yielding OSR, the long rotation would be slightly less profitable than the estimates in the model, but labour, equipment time, and investment levels would be similar.

A winter wheat/OSR short rotation was modelled with biopesticide application the first four months after sowing OSR with at least 2 applications per month. The model is solved for a range of biopesticide product costs and application frequencies. It would be possible to model a similar spring barley/autumn sown OSR short rotation with biopesticide; this was not done in order to reduce model complexity. While there is uncertainty about the cost of the biopesticide product for broadacre crop application, the initial focus was on low cost biopesticide products (<£15/ha/application) such as those formulated from plant derived fatty acids. Higher biopesticide product costs are not economically feasible with current OSR prices. In the model OSR can be sown in September or October.

Results

The LP results show the importance of resolving the CSFB problem. Conventional short rotation winter wheat/OSR without neonicotinoid seed treatment, has the lowest return to operator labour, management, and risk taking, among the alternatives considered for both conventional mechanisation and autonomous equipment (Table 1). Introduction of the long rotation with field beans and linseed increases whole farm returns by £26,000 to £32,000. With low cost biopesticides and twice per month application, returns can be increased another £21,000 to £27,000. Individual farmers with opportunities for other higher profit rotation crops (e.g. potatoes, sugar beets, vegetables) might not see this CSFB effect, but it illustrates why OSR area is dropping rapidly in the UK.

Solutions for biopesticide product costs from £0 to £15/application for two applications per month, show the sensitivity of returns to biopesticide costs. At £15/application the biopesticide OSR activities have completely disappeared from the conventional mechanisation solution and occupy only a portion of the area on the autonomous farm. At a cost greater than £15/application, the biopesticide activities disappear from the autonomous farm as well. The gain for both conventional and autonomous farms from introduction of a biopesticide option for management of CSFB is almost identical for all levels of biopesticide product cost tested (Fig. 1). The "gain" is calculated over the baseline of winter wheat/OSR without neonicotinoid seed treatments, but before introducing the longer rotation or the biopesticide options. The gain for the autonomous farm at the £15/application cost is slightly lower than for the conventional farm because tractor time becomes a binding constraint.

Table 1 - Biopesticide on OSR analysis for a 450 ha arable farm in the UK with conventional and autonomous equipment over a range of biopesticide product costs and application frequencies.

Biopesticide Activity Available	Long Rotation Available	Apply per month	Product Cost per Biopesticide Application, £/ha	Labour Hired days	Operator Time days	Wheat Ha	OSR Ha	Bean Ha	Linseed Ha	Gross Margin £/farm	Return to Operator Labour, Management and Risk Taking, £/farm
Conventional Mechanisation with Human Operators:											
Yes	Yes	2	£15.00	34	88	225	75	75	75	332035	69101
Yes	Yes	2	£10.00	35	97	225	225	0	0	335677	72743
Yes	Yes	2	£5.00	35	97	225	225	0	0	344677	81743
Yes	Yes	2	£0.00	35	97	225	225	0	0	353677	90743
Yes	Yes	4	£0.00	37	105	225	225	0	0	353514	90580
Yes	Yes	8	£0.00	35	107	225	225	0	0	347468	84534
No	Yes	NA	NA	34	88	225	75	75	75	332035	69101
No	No	NA	NA	35	90	225	225	NA	NA	299939	37005
HFH autonomous farm:											
Yes	Yes	2	£15.00	95	92	225	96	65	65	324707	123116
Yes	Yes	2	£10.00	107	86	225	225	0	0	330085	128494
Yes	Yes	2	£5.00	107	86	225	225	0	0	339085	137494
Yes	Yes	2	£0.00	107	86	225	225	0	0	348085	146494
Yes	Yes	4	£0.00	107	97	225	225	0	0	348085	146494
Yes	Yes	8	£0.00	97	103	225	127	49	49	332731	131140
No	Yes	NA	NA	96	90	225	96	65	65	320977	119386
No	No	NA	NA	107	77	225	225	NA	NA	294347	92756

NA = not applicable

Fig. 1 - Gain from biopesticide on OSR compared to the HFH solution without neonicotinoids for conventional and robotic farms over a range of biopesticide product cost for twice per month application.

Solutions for the negligible cost biopesticide (£0/application) over a range of application frequencies show that the retrofitted equipment of the type used on the HFH farm does not resolve the problem (Fig. 2). The gain for the conventional and autonomous farms is similar (Fig. 2), except for the twice weekly application (i.e. 8 times per month), in which tractor time is a binding constraint for both the conventional and autonomous farms. The conventional farm switches some land to the late planted winter wheat and OSR with biopesticides to deal with tractor time constraints. The autonomous farm switches some land to the long rotation in this case. Autonomous tractor time becomes binding with 8 applications per month because smaller equipment (4 m boom) requires about 10 times longer to cover the same area compared to the 36 m boom used with large conventional equipment set. So even though the autonomous equipment can operate 22 hours per day, it still has difficulty making the 8 applications per month.

For the autonomous farm, one solution to the tractor time constraint would be to invest in a 4th autonomous tractor and sprayer (i.e. £19,900). With the 4th tractor, the solution for the negligible biopesticide cost scenario switches back to all winter wheat/OSR rotation with biopesticide and the gain (i.e. £50,915) is slightly greater than that of the conventional farm in spite of the extra equipment cost. For the conventional farm sprayer capacity is lumpier. Acquiring another tractor and sprayer unit to deal with the tractor time constraint is more costly (i.e. £320,000).

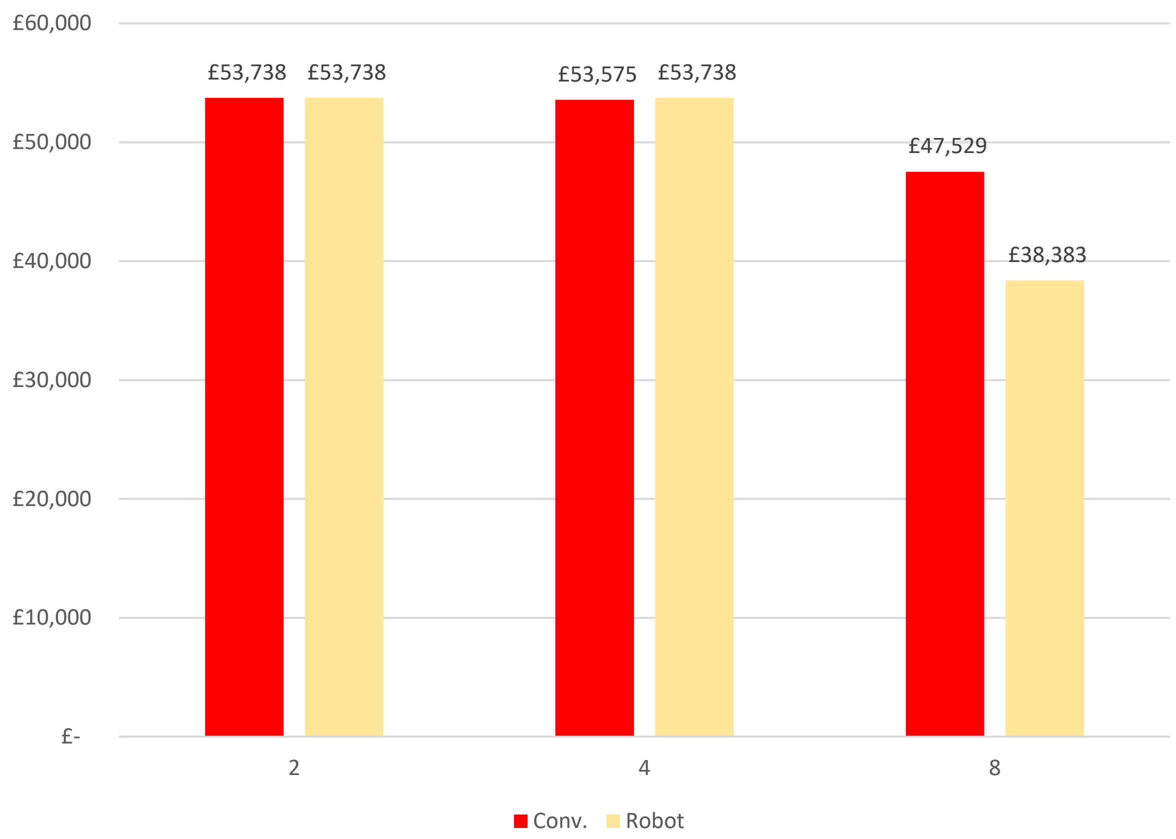

Fig. 2 - Gain from Biopesticides on OSR for Conventional and Robotic Farms over a range of application frequencies per month and with very low cost product

With 8 biopesticide applications per month, operator time also becomes a constraint for the autonomous farm because of the 10% human supervision time assumed. The 10% human supervision time is based on the HFH experience, but it is at the lower end of the range of human supervision time assumptions in the autonomous equipment economics literature. Dewitte (2019) assumes a 50% human supervision time. Many European countries and the US state of California require an on-site human supervisor 100% of the time for autonomous farm equipment. Even if regulation of autonomous equipment allowed less than 10% human supervision time, technical changes would probably be required including artificial intelligence for problem solving to reduce the need for human intervention and automated refilling of the sprayer tanks. The HFH economic analysis assumes that the human supervisors assist with input resupply for autonomous equipment.

Discussion

The primary hypothesis of this study was not supported. At low biopesticide product prices the gain from introduction of the biopesticide option is very similar on conventional and autonomous 500 ha farms with the previously Identified optimal equipment sets. This occurs for the twice per month and once per week biopesticide applications because they can be accomplished mainly with operator labour that would otherwise be unused. The October to January period is not a peak labour or tractor time demand period for the winter wheat/OSR short rotation previously identified as optimal. With twice per week biopesticide applications (8 times per month) the gain is reduced because of October tractor time constraints for both the conventional and autonomous farms.

The October tractor time constraint can be resolved quite inexpensively for the autonomous farm by acquiring another tractor and sprayer. For the conventional farm, equipment capacity comes in bigger, more expensive steps, and is consequently not a profitable option for the scenarios considered.

Conclusions

This study has identified several constraints to use of autonomous equipment for application of low residual biopesticides on OSR, including:

- The volume of water required is a major constraint to use of autonomous equipment. The logistics of transporting and applying that volume of water means that a substantial machine is required. The small, light, inexpensive robots envisioned by some researchers for micro-spraying cannot be used. Research is needed on applications methods and alternative biopesticides that would reduce the water requirement.
- The human supervision time is an important constraint for the autonomous farm when then spray frequency increases. Reducing human supervision time has regulatory and engineering aspects. In some countries autonomous farm equipment must have 100% of the time with human on-site supervision. The engineering aspect is related to AI for problem solving in the field to avoid the need for human attention and to automatic resupply of the biopesticide water mixture without human assistance.
- For both the conventional and autonomous farms the price of the biopesticide product is an important factor. With frequent application the overall cost of the biopesticide quickly becomes burdensome even if the cost per application is relatively low.

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Horizontal price transmission in major EU pork markets

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Abstract

The European Union has made great endeavours during the last decades in order to integrate markets and eliminate barriers that hinder free trade of goods among its members. The stabilization of prices and the pattern of spatial price relationships demonstrate the degree of integration among the geographically separated markets. There is a limited research on horizontal price transmission that examines EU meat markets. Pork production is one of the most important meat sectors across the EU agro-food supply chain. Examining and understanding the price relationships within the EU pork market is important for many reasons.

The study focuses on horizontal price transmission between Germany, Spain, France, Denmark, Netherlands, Poland and Lithuania. The study investigates the development of monthly pork prices (class E) during the period from January 2004 to March 2020. This paper applies econometric tests such as: ADF unit root tests, Bai-Perron test, Engle-Granger cointegration approach, Granger Causality approach and M-TAR (Rose et al. 2019; Jurkėnaitė and Paparas, 2019) allowing us to investigate the relationships of prices between different markets.

We deploy pair wise analysis since it is one of the most common types of analysis when examining price transmission. According to Serra et al. (2006) when examining paired prices, the central market is assumed to be the largest in volume market. In our dataset and examined period, Spain is considered as the leader market and consequently the central market. Several characteristics of this market prompt us to consider Spain as the market which determines prices.

We found that the ADF test indicated that all examined series are integrated of first order. In our empirical results we found support of stable long run relationships among the six examined pairs, which means that the major EU pork markets are co-integrated. Additionally, price transmission in the long run seems to be asymmetric since negative shocks are transmitted with higher intensity than positive-type shocks. Therefore, the validity of the Law of one Price is rejected and the examined pork markets cannot be considered as efficient (Tremma and Semos, 2017; Fousekis and Trachanas, 2016).

Keywords

Agriculture, market, pork, price transmission

Presenters Profile

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