Proceedings of the INFER Workshop on Agri-Tech Economics

18th - 19th October 2019, Harper Adams University, Newport, United Kingdom.

Compiled and edited by
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08.30 - 09.00 **Registration**

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16.30 – 16:45 **Closing of the Workshop**

Local Workshop Organising Committee

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Keynote Presentation: Agri-Tech Economics is Essential to Strategic Planning

Professor James Lowenberg-DeBoer

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Abstract

Agri-Tech Economics is an emerging field of research focused on providing economic insights on the role of agricultural technologies in future farming systems, value chains and trade. In the fast-moving world of technology change, agri-tech economics is essential to strategic planning for farmers, agribusiness and agricultural policy makers. Decisions about on-farm technology adoption, agribusiness service and product offerings, and the future of agricultural tax, regulation and subsidy programs depend on the economics of technology. Some examples of agri-tech economics include: 1) research on the economics of variable rate fertilizer in the 1990s that informed farmer adoption and commercialization plans, 2) benefit/cost analysis of global navigation satellite systems (GNSS) machine guidance in the early 21st Century and rapid adoption, 3) research on profitability of hermetic grain storage and the commercial success of the "Purdue Improved Crop Storage" bags in Africa, and 4) potential role of Hands Free Hectare (HFH) crop robotics economics analysis in agricultural automation. The hope is that the Global Institute for Agri-Tech Economics (GIATE) at Harper Adams University will provide a mechanism for agri-tech economics researchers worldwide to share methodologies, challenges and results. For the participants in the INFER Workshop on Agri-Tech Economics the challenge is to start building the networks that will make GIATE effective.

Presenters profile

Prof. Lowenberg-DeBoer holds the Elizabeth Creak Chair in Agri-Tech Applied Economics at Harper Adams University. He is president-elect 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 84 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.

Keynote Presentation: Economics of Individual Plant Management for Field Crops

Associate Professor Søren Marcus Pedersen

Department of Food and Resource Economics, University of Copenhagen, Frederiksberg, Denmark

Abstract

In the last decade several technologies related to individual plant management and precision farming has gained interest from variable rate application of inputs, section control and auto-steering as well as advanced decision support systems. A recent development of semi-autonomous systems and farm robots is a further development of that process.

Many new start-up companies offer new solutions with apps and decision support systems that incorporate GNSS, positioning and GIS mapping systems in arable farming. Some have reached a commercial level, whereas others are still under development. The intention of this presentation is to give an overview of some promising technologies and systems from an economic and environmental point of view. Different cases will be presented such as variable rate fertilizer application, individual pesticide application as well as potential gains from section control and controlled traffic farming systems in arable farming. Since precision farming as a farm technology will benefit from scale advantages because of relatively large initial costs, farmers with large field areas are among early adopters.

Presenters profile

Søren Marcus Pedersen, Phd is an associate professor at Department of Food and Resource Economics at University of Copenhagen. He works with production and innovation economics, adoption studies and technology assessment in the agri-business sector. Research areas include farm management information systems, economics of precision farming and other smart farming technologies. He has been involved as a project-leader or work-package leader in several EU funded collaborations about precision farming and smart-farming systems, including Future Farm, CTF-Optimove and PamCoba. Currently he teaches in courses about Business Economics, Technology Assessment and European Farming Systems at University of Copenhagen.

Social acceptance of digital farming technologies in Germany

Andreas Gabriel, J. Pfeiffer and M. Gandorfer

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Abstract

Although social acceptance of digital farming technologies (DFT) is of paramount importance, very little research has been conducted in this area so far in Germany. An online survey of the German population provides first results. A mix of questions and analysing methods was used to gain a better understanding of the acceptance of DFT by the population. The composition of the pre-quoted sample (n = 2,012) is representative of the population living in Germany in terms of gender, age, size of place of residence, and education. Beside their relation with, knowledge of, and attitudes and perception of agriculture in general, respondents were asked to rate various statements on DFT on the basis of which the acceptance can be deduced. As examples of DFT, sensors for livestock farming, digital hoeing technology, spot spraying, and near infrared spectroscopy (NIRS) sensors for organic fertilization were chosen. First, the rating of statements was conducted on a general level. Then, respondents were queried their opinions on the use of the four specific technologies, and on public financial support as a means to foster their adoption. Linear regression models show that the main positive influences on respondents' attitudes towards the benefits of digitalization in agriculture are a generally positive attitude towards farming (e.g., animal welfare and preservation of the environment are considered very important) and a positive perception of the German agriculture.

In the next part of the questionnaire, three choice experiments on DFT in selected fields in crop production and animal husbandry were applied to find out in which shaping these technologies are most accepted by the population. In particular, preferences of attribute characteristics in digitalization in dairy farming and weed control and autonomous driving were determined. For each of the three experiments, the participants weighted the attribute values against each other and "unconsciously" decided on the part worth of individual attributes of the technologies presented in random combinations (e. g., weed technology, tractor size, degree of automation in animal control, price of the end product). Results of the three choice sets give first indications that smaller tractors ("swarm robotics") have a higher acceptance than field work done by large autonomous machines. Regarding the animal sector, moderate price increases for dairy products are accepted by the respondents if sensor control and a medium level of automation are used to support animal welfare.

In the last part of the survey, respondents were asked for their spontaneous associations with pictures showing DFT for crop production and dairy farming. When visually confronted with the four specific DFT, the emotional component becomes apparent, which partly results in negative spontaneous associations by respondents, and general criticism of agricultural production processes. The latter applies in particular to DFT in animal husbandry. The paper concludes with a comparison of the three methodological parts of the survey and gives indications for further research and future handling of DFT in farming and society. However,

as agriculture as a whole is criticized by many parties in Germany, it is unlikely that the benefits of digitization alone have the potential to significantly increase the overall social acceptance of agriculture.

Keywords: choice experiment, digital farming technologies, online survey, social acceptance.

Presenters profile

Dr. Gabriel studied Horticulture at the Weihenstephan-Triesdorf University and worked there for more than 10 years as research associate at the Chair of Marketing and Management of Biogenic Resources. During this time he has completed several projects focusing on empirical social research in the fields of horticulture, nutrition and agriculture. After his PhD at the Chair of Economics of Horticultural and Landscaping at the Technical University München in 2018, he additionally supports the project group "Digital Agriculture" at the Bavarian State Research Center for Agriculture in studies on the social acceptance of digital technologies and their adoption in agricultural practice.

Have we become too dependent on GNSS? Evaluating the implications of GNSS outage

Terry W. Griffin[A] and Tyler B. Mark[B]

[A] *Kansas State University, Manhattan, Kansas, USA*

[B] *Department of Agricultural Economics, C.E. Barnhart Building, University of Kentucky, Lexington KY 40546-0276, USA*

Abstract

Constant and reliable access to Global Navigation Satellite Systems (GNSS) is the foundation of precision agriculture across the globe. Farmers rely on GNSS to empower automated guidance, make variable rate applications, and collect data yield sensors, grid soil sampling, and as-applied applications. Specifically, within the United States as of 2016, nearly two-thirds of acreage were planted with tractors equipped with automated guidance while less than half of farms implement variable rate application (Hellerstein et al., 2019). Increasing adoption of technology has been driven by increasing farm size, i.e. farm consolidation, increasing equipment size, desire to increase operational efficiency, and attempts to reduce adverse environmental impacts. However, as farms become more reliant on GNSS to implement their management strategies and operate larger machinery, the cost of a GNSS outage continues to rise. Costs of GNSS outage could rise exponentially as autonomous machinery and robots become more common.

Industry estimates a loss of GNSS access could have a $1 billion per day impact (Berger, 2019). However, these are rough estimates and could be higher or lower depending upon the time of year the outage took place. There are at least six regional or global GNSS systems that are being constructed or maintained. China, Russia, the European Union, India, Japan, and the United States are the primary systems that are in place. In 2019, Galileo experienced an outage that renewed concern for an outage by the agricultural industry. Galileo, which has been in a pilot phase since 2016, experienced multiple outages since deployment. This is just one example of many where these systems can fail for multiple consecutive days. Given potential for an outage, it is essential to gain a deeper understanding of these potential costs at the farm level and across agricultural production regions.

This study builds upon previous work by Griffin et al. (2005, 2008) and Griffin (2009) by estimating the potential economic losses of a transition back to pre-GNSS visual marker references. Summing the farm-level value of GNSS adoption of navigation technologies for an existing farm across a region proxies for the cost of a regional GNSS outage.

To address the economic feasibility of GNSS navigation technologies, a mathematical linear programming (LP) model was formulated for a representative 1,214 hectare U.S. Cornbelt farm. Several scenarios were compared: 1) a baseline scenario with foam, disk or other visual marker reference without GPS navigation; 2) automated guidance with satellite subscription correction; and 3) automated guidance with a base station (RTK) and +/- 1 cm accuracy. Sensitivity analyses were conducted on the equipment sizes utilized within the model. Evaluation of whole-farm returns over incremental management scenarios builds upon

previous research by evaluating the changes to inputs costs. This study is of interest to farmers considering the best use of precision technology, agricultural industry marketing the technology, university researchers searching for optimal management of technology, and agricultural and international policy makers.

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Presenters profile

Dr. Terry Griffin is the Cropping Systems Economist at Kansas State University. His research includes 1) valuation of farm data within the farm gates and in aggregated communities, 2) farmers' technology adoption paths, and 3) spatial statistical techniques to analyse on-farm experiments. For his achievements in advancing digital agriculture, Griffin has received the 2014 Pierre C. Robert International Precision Agriculture Young Scientist Award, the 2012 Conservation Systems Precision Ag Researcher of the Year, and the 2010 PrecisionAg Award of Excellence for Researchers. He serves as Treasurer of the International Society of Precision Agriculture. In addition to presenting across North America, Terry has delivered invited presentations in Europe, Africa, and Australia.

Tyler Mark is an associate professor of production economics in the Department of Agricultural Economics at the University of Kentucky. His applied research interests include digital agriculture, simulation methods, broadband availability in rural areas, precision agriculture, precision dairy, dairy policy, renewable energy feedstocks, and hemp economics. Funded projects through USDA-NIFA, USDA-RMA, NSF, and industry partners provide the resources needed to investigate the profitability of Kentucky farmers, broadband internet's impact on precision agriculture data transmission, the economic aspects of hemp production in Kentucky, dairy policy in the Southeastern United States, and the development of the Kentucky economy.

A Whole Farm Economic Analysis of High Speed Planting's Potential for Increased Net Returns and Management of Days Suitable for Fieldwork Risk

C. Dillon, J. Shockley and T. Mark

Department of Agricultural Economics, C.E. Barnhart Building, University of Kentucky, Lexington KY 40546-0276, USA

Abstract

While recent excitement over the latest advancements in high speed planting grows, further clarification of the promise of the technology by the scientific community is needed. As farm managers contemplate the opportunities afforded by high-speed planters (HSPs) in their business operations, economic assessment will be crucial. This study updates and expands upon an earlier ECPA (European Conference on Precision Agriculture) paper and examines the opportunities of HSP for a representative Western Kentucky 1000 ha commercial corn and soybean farm under no-till, rain fed, 2-year rotation, conditions. Study objectives are to:

1. Examine the potential for high speed planting to enhance whole farm profitability and reduce suitable field day risk under different speed and hours worked per day assumptions compared to conventional planting technology,

2. Investigate the production practice management implications optimally conducted when adopting high speed planting technology and

3. Conduct sensitivity analysis of the economic gains of HSP for ownership of different planter sizes

Benefits of HSP include potential yield improvements because of being able to plant more during the optimal window and opportunity to reduce the weather-associated risk of facing field conditions unsuitable for planting. Another benefit is cost savings with a reduction in labour costs, fuel, repairs and maintenance on the tractor and the interest on operating capital of these expenditures. However, additional operating costs of repairs and maintenance associated with the planter must also be considered as well as the accompany interest on operating capital. Ultimately, the question facing decision makers is whether the benefits outweigh the costs, especially the costs of ownership like depreciation and interest.

A whole farm planning optimization model is formulated using linear programming. While a simpler approach of a partial budget analysis might be preferable, it's inability to capture yield differences attributable to optimal planting dates in the face of field operation competition as well as the interactive influences of planting time with other production practices (seeding and fertilization rate, seed variety). Decision variables include production of corn and full season soybean under alternative production management practices and marketing. Constraints include land, suitable field time for all farm machinery operations, rotation and differing soil ratio constraints equations. The Charnes and Cooper right hand side method for assessment of days suitable for fieldwork risk is used.

The base case scenario utilizes autosteer for a 16-row planter assuming a risk neutral (median) level of suitable field day likelihood and 16 hours per day worked under conventional planting speed (8 km/hr). The first study objective will investigate effects of various likelihoods for suitable field days and hours spent planting per day for speeds 150% and 200% of the base planting speed assumed.

While a very modest increase in net returns is found, farm managers are virtually indifferent at 150% speed under median SFD and 16 hours worked daily. Results demonstrate slightly more favourable economic potential under double speed planting with additional farm net returns of $1500 or about 0.4%. Contrary to expectations, the more limiting 12 hours/day displays 150% as being economically inferior to conventional speed planting. Notably, the farm mean yield of corn remains unchanged until the doubling of normal planting speed at which point HSP is again economically superior. There is some evidence of opportunity for HSP planting to reduce suitable field day (SFD) risk. Under a 60% likelihood of SFD, net returns increased by $757 and $2240 for 1.5 times and double base speed respectively as compared to $26 and $1509 under median SFD.

The general emphasis on the higher yielding earlier planting dates for soybean and corn can be seen in optimal production management plans. Under the base case, conventional planting speeds allowed the producer to plant 70% of soybean during the earliest week (around Apr 22nd) with the next two weeks completing soybean planting. For corn planting, conventional planting speed practice leads to 86% planted during the first week of planting (Mar 25th) but the next week is instead dedicated to other farm operations before completing corn planting in the third available week (Apr 8th). Competing field operations of pre-plant herbicide application for soybean with corn planting and tight corn harvest windows explain these shifts in corn planting time.

Sensitivity analysis upon planter size unsurprisingly reveals HSP under the 12-row planter scenario demonstrated slightly more pronounced economic gains than the 16-row case. Specifically, increased net farm returns of $4326 and $6917 for 150% and 200% conventional speed respectively are computed. With no change in production management practices under the various planting speeds when using a 24-row planter, high speed planting is of course never justified economically.

In conclusion, a portion of ownership costs inherently is recuperated through operating cost savings (labour, fuel, etc.) but yield differential assessment can be more involved to evaluate thus strengthening justification for a whole farm optimization model. Competing machinery operations and opportunities for selection of alternative production practices complicate an accurate assessment of possible yield increases that might be enjoyed from high speed planting. Evidence is found for the opportunities of modest increases in farm net returns and suitable field day risk management potential under some circumstances. Interplay between hours worked per day, planter speed, planter size and farm manager behaviour sometimes lead to seemingly unexpected results, cautioning against oversimplified and broad generalizations of the economic potential for high speed planting.

Presenters profile

Dr. Carl R. Dillon is a Professor in the Department of Agricultural Economics at the University of Kentucky. His general research interests and experiences are in production economics and farm business management. He is an expert in the application of quantitative techniques, especially mathematical programming, to agricultural economic analysis. His primary research focus has been upon evaluation of the potential of alternative production practices and new technology for profitability and risk management. Most recently, he focuses upon the area of precision agriculture.

Variable rate technologies – costs and benefits of increasing information accuracy

Karin Späti, Robert Huber and Robert Finger

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Abstract

Improving nitrogen use efficiency is crucial for tackling systematic agricultural challenges. Nitrogen fertilization with site-specific management using variable rate technologies (VRT) is expected to increase nitrogen use efficiency and reduce nitrogen losses by tailoring nitrogen application to crop, soil and other environmental traits (del Pilar Muschietti-Piana et al., 2018, Lowenberg-DeBoer, 2015, Finger et al., 2019). Despite possible economic and environmental benefits (Basso et al., 2016, Meyer-Aurich et al., 2010), adoption rates of VRTs in Europe are rather low (Barnes et al., 2019). One of the key barriers is that the cost of VRTs can outweigh the benefits for the mostly small-scaled family farms that still prevail in Europe.

Recently, technological developments have broadened the range of cost-effective technologies for crop scanning (e.g. satellites, drones) and nitrogen application (Walter et al., 2017, Finger et al., 2019). These are not yet included in VRT literature.

We investigate the conditions under which these new technologies can be applied in small-scale agricultural settings. We analyse the benefits and costs of different approaches to VRT, i.e. the use of different sensors (from handheld devices, drones to satellite images). We conceptually investigate the applicability of different VRT depending on different economic and ecological conditions (e.g. field size, heterogeneity etc.).

Results from our conceptual model show which type of technology (or suite of technologies) is profitable under different environmental conditions (field size and heterogeneity) and different institutional arrangements for technology use (e.g. individual, joint ventures, contractor). In farming systems with small and heterogeneous management units, technologies with higher resolution and accuracy can be the key to successful implementation of VRTs. At the same time, the cost for more precise technologies in small agricultural systems crucially depends on how investment in new technology is made. Therefore, different forms of cooperation could be a key factor in the adoption process of VRT in small-scale farming systems.

Keywords: Variable rate technology, site-specific management, technology adoption

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Presenters profile

Karin Späti holds a Bachelor's degree in Environmental Sciences from ETH Zurich with a focus on forests and landscapes, as well as a Master's degree in Environmental Sciences, focusing on evolution and ecology. Since June 2018, she is a PhD student in the Agricultural Economics and Politics Group at ETH Zurich. Her interdisciplinary PhD project focuses on digital innovations for more sustainable agricultural production techniques.

The Value of Conducting On-farm Field Trials Using Precision Agriculture Technology: A Theory and Simulations

David Bullock, Taro Mieno, and Jaeseok Hwang

Department of Agricultural and Consumer Economics, University of Illinois, Urbana, Illinois, USA

Abstract

First, a simple economic theory is presented to argue that a) current use of precision technology is low because many potential users possess too little information about crop yield response to use precision technology profitably; and b) if the economic supply curve of that information can be shifted out, use of the technology will increase. Second, results of a Monte Carlo simulation are presented to gauge the practicality of this idea of on-farm precision experimentation (OFPE) to increase the information needed to increase the demand for precision technology. Those simulations quantify (a) how the values of site-specific technology and uniform technology change as the number of years of on-farm experimentation increases, (b) how the value of site-specific technology (as compared to conventional, uniform rate technology) increases as the number of years of on-farm precision experimentation increases, and (c) the value of OFPE information to farmers who otherwise would follow university-based uniform rate management advice. Simulation results were that, on the simulated field, (1) OFPE could not provide sufficient information to make variable-rate input application more profitable that uniform-rate input application, but that (2) one or two years of OFPEs on the field provided information that increased farm profits for a farmer who otherwise would follow the University of Illinois "best management practice" recommendation.

Presenters profile

David S. Bullock is a Professor in the Department of Agricultural and Consumer Economics at the University of Illinois, USA. He received his Ph.D. from the Department of Economics at the University of Chicago in 1989. The focus of his current research is on the economics of agricultural technology and information. He is the Principal Investigator of the four-year USDA-sponsored "Data-Intensive Farm Management" project, which works with commercial farmers, using precision agriculture technology to conduct large-scale, on-farm agronomic experiments. He and colleagues use the resultant data to help farmers increase the efficiency of their nitrogen fertilizer and seed management strategies.

The Farm-to-Fridge Value Chain: Participants' Roles and Driving Productivity through Technology Interventions

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Abstract

The value chain of the Indian dairy industry consists of dairy farmers, collection centres, chilling centres, processing plants, retailers and consumers. The objectives of the study are to map the processes and operational challenges existing in the dairy value chain, estimate profitability of the participants at the farm-levels to gauge their potential in undertaking entrepreneurial initiatives, study roles of the privately-owned processing plants in the supply chain, and identify business models of startups in the dairy ecosystem who drive productivity through technology interventions. Exploratory research through multiple field visits, in-depth interviews and personal observations in West Bengal (eastern India) and Bangalore have formed the basis of this study. Using case study format, the roles of the different intermediaries in the value chain have been analysed to develop insights on their entrepreneurial abilities and intent.

The findings reveal the largely fragmented, unorganized dairy industry where the channel members majorly operate in silos with linkages only to their immediate backward and forward partners, in a myopic manner. At the farm level, only the chilling centres have sufficient profitability to undertake value-adding entrepreneurial initiatives. The marginal dairy farmers are at subsistence level and hence unable to participate in value creation. The private processing plants are corporate entrepreneurs and their interactions with chilling centres are confined to that of supplier-manufacturer, to ensure seamless supply of milk for their manufacturing processes. They do not engage with the small dairy farmers. In these circumstances, new-age start-ups that create social impact while operating as a viable, for-profit organization, effectively bridge the gaps in the dairy value chain by intervening at all its nodal points and providing technology solutions to create additional value. Farmers are at the core of the dairy processes as they produce the milk and any improvement in the value chain ultimately gets back to the farmer through better prices and better market linkages.

Presenters profile

Dr. Mohua Banerjee is a Professor and Dean in IMI Kolkata and has over fifteen years of teaching experience in distribution, retail and marketing communication. She completed her M.Com in Accountancy and Ph.D. in Commerce from University of Calcutta. Mohua has received the "CMI Level 3 Award in First Line Management" from Chartered Management Institute, UK, and is an Independent Director in Electrosteel Castings Limited. She has consulted in telecom sector and done practice-oriented retail research with Oxford Institute of Retail Management, University of Oxford. She has developed Retail Management curriculum for National Skill Development Mission, Ministry of HRD, India.

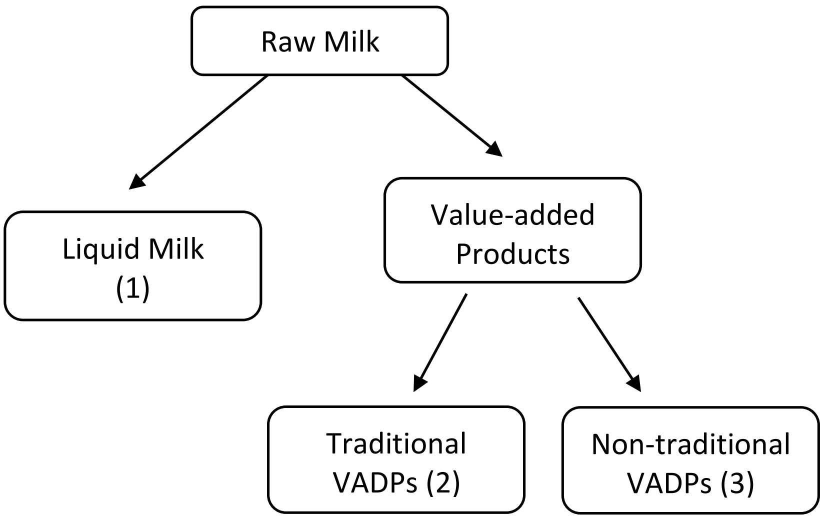
Dairy Industry in India

India is the world's largest milk producer. The Indian dairy industry accounts for more than 21 percent of the total global production. Most of the milk is produced by small, marginal farmers and landless labourers and therefore, the development of the dairy industry has become an important component for social and economic change that is expected to improve income and quality of life for the dairy farmers. As per industry practitioners' estimates, 7.6 percent of India's GDP is from dairy ($3 billion) and in terms of scale 76 million dairy farming families and about 300 million cattle are involved, with each farmer owning 2-4 cattle on an average.

One of the major attributes of the Indian dairy sector is that it is predominantly unorganized. Almost half of the milk produced is consumed on farm by the household that produces it and the remaining half is available for sale. Organized, private sector players who use modernized processing plants and market the milk through distribution channels are just seven percent of the overall market, while cooperatives account for an additional eight percent. Small-scale unorganized milk vendors sell loose milk directly to households and sweet/paneer (cottage cheese) shops and contribute to 36 percent of sales.

The Indian dairy sector can be broadly classified into three categories: Liquid milk, Traditional Value-added Dairy Products (VADPs) like Ghee (clarified butter), Cheese and Butter milk, and Non-Traditional Value-added Dairy Products such as Yogurt, Shrikhand (strained yogurt dessert), Flavoured milk, Condensed milk and Skimmed milk powder (Figure 1).

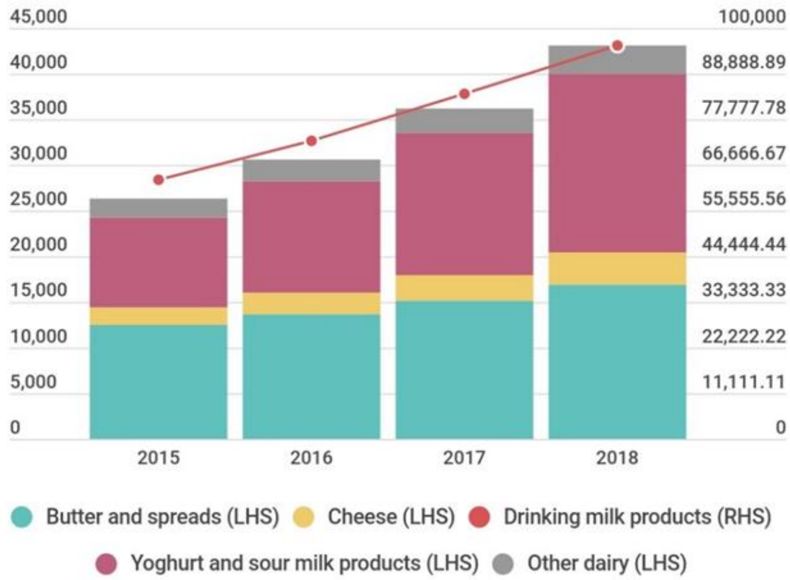
Figure 1. Classification of Dairy Products



Though consumption of liquid milk dominates the sector, with the growth in premiumization and diversification of the consumers' needs, the consumption pattern of dairy products in India is gradually shifting from traditional to VADPs in urban and rural urban areas. This shift in the consumption trends has proven to be beneficial for manufacturers since margins in VADPs are more than twice the margins in the liquid milk segment.

As per the reports of National Dairy Development Board (NDDB), the demand in the dairy sector will increase to 200 million tonnes by 2022 from 132 million tonnes in 2013. The Indian dairy sector is valued at Rs. 1,380 billion (2018). It is the second largest segment in packaged foods. The household consumption survey by National Sample Survey Office (2011-12), indicates that the average milk consumption has increased from 2004-05 by 470 ml per month in rural area and by 315 ml per month in urban areas. According to Euromonitor, India's milk-based drinking products is a market of Rs. 1,000 billion (2018) and growing at 14-15 percent year-on-year. Even the smallest category, cheese, was worth Rs. 35 billion and growing at 18 percent. The fastest growing categories are yogurts and sour milk drinks which are projected to grow at 19 percent CAGR until 2023 (Figure 2).

Figure 2. Break-up of the dairy market (Figures in INR crore (1 crore = 10 million), Source: Euromonitor)

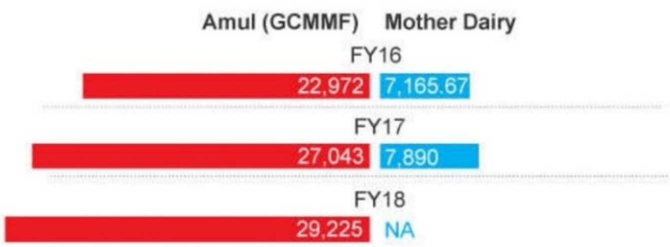


The major players in India's dairy sector are Dairy Cooperatives and Private Dairies. There are 170 Milk Producer Cooperative Unions and 15 State Cooperative Milk Marketing Federations. Some of the famous brands created by Cooperatives are Amul (Gujarat Cooperative Milk Marketing Federation), Saras (Rajasthan Cooperative Dairy Federation Limited), Nandini (Karnataka Cooperative Milk Producer's Federation Limited) and Gokul (Kolhapur District Cooperative Milk Producer's Union Limited). Amul is the largest player in the Indian dairy business and the other major competitors that account for the major share of processed milk sold in India are also State Cooperatives owned by milk farmers, including National Dairy Development Board's Mother Dairy which ranks second (Figure 3). The cooperatives in the milk business have a major stronghold that has been hard to dislodge by both the national and the foreign private enterprises.

The Private Dairies consist of both domestic and international players. Over the past few years, the domestic players such as Parag Milk Foods, Kwality Ltd., Keventer Agro Ltd. have marked their presence in the Indian dairy market. The rapid growth of the Indian dairy market has also attracted the international players to invest in India. Two of the major investors are:

- Lactalis (acquired Prabhat Dairy for Rs. 17 billion)
- Danone SA (invested Rs. 1.82 billion for an undisclosed stake in Mumbai-based startup Drums Food International)

Figure 3. Sales of the top two dairy brands in India (GCMMF – Gujarat Cooperative Milk Marketing Federation, Figures in INR crore (1 crore = 10 million), Source: ET Prime)



In India, some FMCG food brands such as Nestle, Britannia and Coca Cola (with Vio) operate through third-party manufacturers for procuring milk and processing the products while they confine their initiatives only to branding and marketing the products. In 2019 Patanjali (an Ayurveda-based consumer goods company) has launched its range of milk and milk products in the Delhi/NCR region and to match competition from Amul and Mother Dairy, it is broadening its distribution as well as its sourcing bases. It is connecting with 100,000 dairy farmers from over 2,000 villages from Rajasthan for this purpose.

The purpose of this exploratory research is to ascertain the scope of the dairy value chain entities in creating critical impact through sustainable innovations. Primary research through multiple field visits, personal observation and in-depth interviews has formed the basis of this study. Using case study method, the roles of the different intermediaries in the value chain have been analysed in order to develop insights based on the activities and perspectives of the practitioners. The specific objectives of the study are fourfold:

i. Map the processes and operational challenges in the dairy value chain

ii. Estimate profitability of participants at the farm levels to gauge their potential in undertaking entrepreneurial initiatives

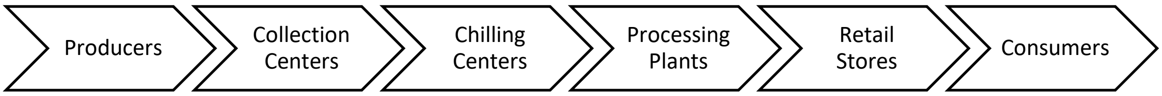
iii. Study roles of privately-owned processing plants in the supply chain, and

iv. Identify business models of entities in the dairy ecosystem who drive productivity through technology interventions.

The dairy value chain processes

The Value Chain of the Indian dairy industry can be depicted through a flow chart with six major entities as its core participants (Figure 4).

Figure 4. Value Chain of the Indian Dairy Industry



Producers: They are the local milk producers or dairy farmers. The responsibility of a dairy farmer is to manage the herd, supply inputs for the dairying in the form of fodder, animal feed plant, and provide veterinary services for the animals. The farmers are also responsible for milking the animals and each farmer produces an average of 2-3 litres of milk with 2-3 animals.

Collection Centers: Collection centers are the first hop in aggregating milk from multiple dairy farmers and currently there are 0.5 million such centers in India while growing at 12 percent annually. These are spread in rural areas and are equipped with small reception tanks, a milk pump and a small milk-cooling tank. The small centers procure milk from a minimum of 5-6 farmers and the numbers extend to 60-70 farmers in the larger formats.

Chilling Centers: The chance of spoilage of milk is reduced by chilling milk within four hours of milking the cows. Chilling centers are set up at the village level and they procure the milk from the collection centers. About 10-20 collection centers aggregate milk into one chilling center. They have refrigeration units and an uninterrupted power supply. Chilling Centers are sometimes considered similar to collection facilities and their larger operating capacity is the only characteristic that distinguishes them from the other.

Processing Plants: Processors are industrial plants where the raw milk is converted into a wide variety of dairy products, including pasteurized UHT Milk and VADPs with the aid of technology.

Retail Stores: Retail stores stock varied dairy product line stock-keeping units as a part of their brand architecture and ensure product availability within consumers' reach, for their purchase decisions.

Consumers: Consumers are both households and commercial consumers of dairy products.

Operational challenges in the dairy value chain

Several constraints are discouraging farmers from continuing with dairy farming, resulting in a direct effect on milk production in terms of quantity and quality. This section highlights some major constraints that exist at each nodal point of the value chain.

1. Issues and Challenges at the Dairy Farmers' Level

Farmers with small farm holdings deal with problems like inadequate nutritious feeding of animals, poor housing for dairy animals, low genetic potential of animals, high disease incidence, lack of availability of veterinary services and animal screening facilities, mainly due to lack of resources. Other issues relate to insufficient knowledge on milk quality, clean milk production and proper feeding of animals. Lack of chilling capacities, high production costs and delayed payment of dues, non-remunerative prices for milk produce, exploitation by middlemen, inadequate number of cooperative societies, insufficient financial support for scientific dairy farming and poor irrigation facility for growing fodder crops for the livestock animals are some of the major operational challenges of the dairy farmers.

2. Issues and Challenges at Collection Centers/Chilling Centers

Dairy producers are predominantly small fragmented farmers with marginal output per farmer which makes it difficult for Collection/Chilling Centers to ensure their reach to the farmers located in the remotest locations in the villages. In situations where intermediaries get involved to render aggregation services from the farm level to these centers, margins are further reduced and it also results in manipulation/adulteration of the milk. Absence of a screening system for milk testing and identifying fair value of milk, unavailability of chilling facilities at the collection center, and also a lack of infrastructure in terms of village roads and power supply in villages are the major challenges.

3. Issues and Challenges at the Processing Plants

Meeting the seasonal spikes in milk demand, the ability to measure the quality of milk at source and traceability of the milk from the farmer to the processing plant are some major issues. Farmers are not able to understand the complex logic of payments to them based on solid non-fat (SNF), fat and quality of milk that they supply. Capabilities are lacking for monitoring compelling factors such as making payments to milk farmers based on tanker routes or distances travelled, as there are not enough resources. Inventory requirement is not determined based on predicted future market demand or consideration of the shelf-life of the milk. The quantity of milk supplied also fluctuates seasonally (in the rainy season the milk supply is high due to easy availability of fodder). Addressing growing food concerns from consumers, lack of technology for fat accounting and tracking effectively fat loss in the process of production, are some of the major challenges at this stage.

4. Issues and Challenges for Marketing

Majority of the Indian dairy market is still unorganized. Penetration in the rural markets is still low due to lack of cold chain infrastructure and insufficient route-to-market strategies by the dairy companies. Certain consumer beliefs, e.g. processed milk is less healthy and does not have the same nutritional content as fresh milk that is procured directly from a dairy farmer, also lower the acceptability of the consumer base towards processed and packaged milk.

Profitability estimations of participants at the farm levels to gauge their potential in undertaking entrepreneurial initiatives

In the value chain of a typical dairy industry the milk produced by dairy farmers is aggregated at Collection Centers, treated at Chilling Centers, processed to milk and milk-based products at the Processing Plants and distributed through dairy cooperatives or private companies to retail outlets to the consumer. It is important to identify whether intervention opportunities exist at each level for mitigating operational challenges and driving efficiencies in the value chain through innovative use of technology, field extension services, etc. Intervention at any nodal point that improves productivity in the value chain will ultimately enable all the partners to attain higher profits and growth. In the course of an in-depth interview, venture capitalists like Ankur Capital mention that though the farmer owns his cows, manages them on the field, takes risks in the course of maintaining his cows and collecting the milk like an entrepreneur, he is not considered as an investible entrepreneur from the VC lens. Yet without access to funds, whether generated through business or accessed through loans, interventions for improvement are not possible.

In this section, the study makes some profitability estimations of the farm level value chain partners – VLCC owners and dairy farmers, to identify whether they generate adequate funds in the course of their businesses to operate as entrepreneurs, build backward linkages with dairy farmers and develop sustainable ecosystem in the villages for seamless sourcing of milk. The calculations are based on personal observation undertaken during a field-visit to Mini Dairy (a VLCC in rural West Bengal) and adjacent dairy farms, and the data has been extracted from the primary interviews with the VLCC owners and farmers.

Case Study of Mini Dairy (VLCC) to ascertain its profitability for undertaking entrepreneurial initiatives

Mini Dairy was started in the year 1990 by Mr. Anup Kumar Ghosh. It is located in Shantipally, a rural town near the city of Kolkata, in the state of West Bengal. With a storage and processing capacity of more than 70,000 litres, it operates seven days a week and processes on an average 30,000 litres of milk per day. On its premises, its infrastructure includes a small laboratory for testing milk quality.

Process

Mini Dairy receives milk in three shifts (Table 1) from more than 2,000 farmers located within 12 kilometres in nearby villages. As soon as the milk vehicle reaches Mini Dairy, each container is tested separately to determine the quality of the milk before mixing it with the rest of the milk in the tank. Farmers are paid based on the quality of the milk as determined by the SNF and fat content of the milk. The milk is then filtered for removing the husk or any other solid particles that may be present in it, following which it is either chilled or pasteurized for safe storage. At the time of milking, the temperature of milk is approximately 37°C. To stop the growth of micro-organisms, minimise bacterial load and to maintain the quality as per international standards, the milk is to be quickly chilled to 4°C.

Table 1: Daily receipt of milk in three shifts at Mini Dairy

	Time	Litres
Morning Shift	6:30 A.M.	4,000
Afternoon Shift	2:00 P.M.	6,000
Evening Shift	7:30 P.M.	20,000

Milk is stored in these containers till the vehicles of the dairy processing plants (such as Mother Dairy, Keventer, etc.) arrive to take delivery of the chilled milk. Pasteurization, on the other hand, leads to the killing of bacteria and is usually done when the milk is transported for longer durations to distantly-located processing plants. It increases the longevity of the milk's freshness.

Facilities/services provided by Mini Dairy to dairy farmers

Mini Dairy assumes the role of a dairy entrepreneur and provides various kinds of support facilities to the dairy farmers. It enables Mini Dairy to build a relationship with them which helps it to streamline the sourcing of desired quantity of milk regularly from the dairy farmers, in the absence of any written contract binding the dairy farmers to Mini Dairy. On their part, the dairy farmers too are assured of a fixed amount of their milk production being absorbed daily by Mini Dairy and feel inclined to maintain a steady supply of milk to the VLCC. On an average Mini Dairy spends Rs. 600,000 monthly, to provide farmers with basic facilities such as veterinary services and medicines for the animals (Table 3, Note No. 2 – Cost of Facilities). Mini Dairy also extends credit for purchase of cattle to the farmers as it is almost impossible for a small farmer to spend Rs. 50,000 as a one-time down payment for the purchase of cattle. They charge nominal or no interest from the farmer and the amount is realized as a deduction from every payment due in favour of the dairy farmer for the milk supplied to Mini Dairy.

Based on some data inputs collected on-spot during the field visit, following are some projections on the average revenue and profitability that a Dairy Entrepreneur like Mini Dairy may earn in the normal course of business.

A. Cost Structure and Profitability Analysis of a VLCC

a. Milk quantity processed by a VLCC in litres

Table 2: Milk quantity processed by a VLCC

	Litres
Daily Milk Processed	30,000
Monthly Milk Processed	900,000
Yearly Milk Processed	10,800,000

To operate, the VLCC requires 32 people with an average cost of Rs. 16,000 per employee. Other than employee cost, operating cost per month (power, depreciation, fuel, testing of milk, etc.) is Rs. 400,000. Also, free facilities are provided to the farmers (veterinary services, medicines for the animals, etc.) who supply them milk. The cost of these free services is approximately Rs. 600,000 per month (2,000 farmers at an approximate cost of Rs. 300 per farmer per month).

b. Cost to the VLCC (per litre of milk)

Table 3: Cost to the VLCC per litre

	Per month (Rs.)	Cost per litre (Rs.)
Procurement Rate		**25**
Employee Cost		
Total Employees	32	
Average employee cost per month	16,000	
Total Cost per month	512,000	
Employee Cost per Litre		**0.57**
Cost of Operation of the processing units (Power, Depreciation to Machinery, Fuel, Testing, etc.) per month	400,000	**0.44**
Working Capital Cost (Note 1)	38,219.18	**00.04**
Cost of Facilities (Free Medicines, Veterinary Services, etc.) (Note 2)	600,000	**0.67**
Total Cost per Litre		**26.72**

Note No.1

Investment in Working Capital	
Mini Dairy receives payment from a Dairy Company in 15 days but pays the Dairy Farmer in 10 days. Therefore 5 days is the investment duration of the working capital.	Cost @ 10% p.a.
Payment received from Dairy Company (A)	1,198,356.16
Payment to Farmers (B)	739,726.03
Net Cost of Working Capital (Yearly) (A-B)	458,630.14
Net Cost of Working Capital (Monthly)	**38,219.18**

- Mini Dairy bills the Dairy Company every 15 days. Therefore, it receives payment from its debtor in 15 days of time. On the other hand, it pays to the Dairy Farmer every 10 days.
- Cost of funds is assumed @10% p.a.
- Cost of interest for Payment received from the Dairy Company
  Yearly Revenue × 10% × (Days outstanding/365) = 27 × 10,800,000 × 10% × (15/365) = Rs. 1,198,356.16
- Working capital required reduced by 10 days billing period to Dairy Farmers
  Yearly Payment × 10% × (Days outstanding/365) = 25 × 10,800,000 × 10% × (10/365) = Rs. 739,726.03

Note No. 2

Free services include veterinary services, medicines for the animals, etc. which cost them Rs. 600,000 per month. They provide free services to 2,000 farmers which cost them Rs. 300 per farmer per month.

Cost of Facilities	**(Rs.)**
Cost incurred per Dairy Farmer per month	300
Total No. of Farmers dealt with	2,000
Cost of facilities per month	**600,000**

c. Calculation of Revenue and Profitability of the VLCC

Table 4: Calculation of Revenue and Profitability

Revenue and Profit Calculations	**(Rs.)**
Sale Price per litre	27
Total Revenue (10,800,000 litres × Rs. 27.00)	291,600,000
Less (-) Total Cost (10,800,000 litres × Rs. 26.72)	288,602,630
Profit (Yearly)	**2,997,370**

Based on the above calculations, the projected annual profit for a VLCC like Mini Dairy is approximately Rs. 3 million. Their existing cost structure and profitability justify the initiatives that they take to provide basic support services to the dairy farmers, establish backward linkages with them and streamline the sourcing activities in the dairy supply chain. They also have adequate funds to fuel future innovation and growth in their operations and business model, should they develop the awareness and necessity of ensuring better quality of the milk for e.g., by bringing traceability in the supply chain. Such initiatives are expected to translate to better prices for the milk that will ultimately benefit the marginal dairy farmers as they are the producers of the milk, apart from also enhancing the VLCC's profitability.

B. Cost Structure and Profitability Analysis of a Dairy Farmer

Estimations of the average revenue and profitability of an average Dairy Farmer associated with Chilling Centers like Mini Dairy have been calculated in this section.

a. Cost per cow per day

A Dairy Farmer incurs a cost of Rs. 250 per cow per day for fodder and maintenance. Dairy Farmers employ caretakers who provide the labour for basic service help in managing the cows and one caretaker can manage 12 cows and comes at a cost of Rs. 400 per day. Therefore, per cow per day cost of caretaker is Rs. 33.33.

Table 5: Cost per cow per day

Cost per cow per day	**(Rs.)**
Cost of fodder and maintenance	250
Cost of labour	33.33
Total Cost per cow per day	**283.33**

A cow on an average gives 12 litres of milk per day. Therefore, the variable cost of one litre of milk to Dairy Farmer is Rs. 23.61.

b. Revenue per cow per day

From the 12 litres of milk produced by a cow per day, VLCC owners mention that 45 percent is sold by a Dairy Farmer to sweet shops and paneer (cottage cheese) shops in the vicinity markets at an average price of Rs. 32. The remaining 55 percent is supplied to the VLCC at a lower average price of Rs. 25.

Table 6: Revenue per cow per day

Revenue per cow per day			
Milk sold to	**Price (Rs.)**	**Litres**	**Revenue (Rs.)**
Sweetshops (45%)	32	5.4	172.8
VLCC (55%)	25	6.6	165
		12	337.8

Therefore, the average revenue per litre to the farmer is Rs. 28.15.

c. Profit per litre of Milk sold by Farmer

Table 7: Profit per litre of Milk sold by Farmer

Profit per litre of milk sold	**(Rs.)**
Average Revenue per litre (A)	28.15
Average Variable Cost per litre (B)	23.61
Fixed Cost per litre (C)	0.71
Profit per Litre (A-B-C)	**3.82**

An Indian cow costs approximately Rs. 50,000 to a Dairy Farmer and gives on an average 70,000 litres of milk in its lifetime. Hence, apportioning this purchase (fixed) cost to the cow's lifetime production of milk entails a fixed cost of Rs. 0.71 per litre. Thus, profits that accrue to the dairy farmer are Rs. 3.82 per litre of milk sold. This highlights the subsistence level existence of the small dairy farmers' and their lack of resources that brings with it the ensuing problems like inadequate nutritious feeding of animals, low genetic potential of animals, high disease incidence and lack of availability of veterinary services.

Though the dairy farmers shows some entrepreneurial initiatives by owning the small number of cows, milking them and as a stakeholder participating in the flow of milk upward the value chain, it is almost impossible for them to create their own infrastructure for improving the quality of milk, such as setting up chilling infrastructure, etc. that will enable them to chill/store the milk at the desired 4°C promptly before transporting the milk upward the value chain. Clearly, they are not in a position to grow their businesses and scale up to the next level (e.g. maintain 5-7 cows on their farms) without any external interventions from other mature participants in the dairy industry ecosystem.

Role of privately-owned processing plant companies in the supply chain

Moving further up the value chain, this study now examines the role of the privately-owned processing plants in the dairy ecosystem. The central question is, given their financial muscle, do these entities pursue entrepreneurial opportunities and innovate in their businesses, develop backward linkages that connect them to the dairy farmers, and cultivate social inclusivity so as to derive synergy for all participants in the dairy industry. To map the particular dairy value chain in the eastern region of India (state of West Bengal) that has been discussed so far, this section of the study focuses on one of the private processing plants to which Mini Dairy supplies chilled milk – Keventer Agro Ltd. For the purpose of this study, Keventer's operational strategy for attaining growth and market consolidation as advocated by its senior management, is analyzed through the lens of corporate entrepreneurship using press releases and reports.

Instance of Keventer Agro Ltd. (Processing Plant) to determine its role in undertaking entrepreneurial initiatives

Keventer Agro Ltd. was India's first dairy project in a public-private partnership model that was launched under Operation Flood Phase III in 1996, as a tripartite venture between the West Bengal Milk Producers Federation Ltd., Keventer and the National Dairy Development Board (NDDB). NDDB later sold its 10 percent stake to Keventer and in 2017 the West Bengal government sold its 47 percent stake in Metro Dairy to Keventer for an estimated Rs. 855 million. Metro Dairy is now a 100 percent owned-subsidiary of Keventer Agro Ltd. The processing plant is located at Barasat on the outskirts of Kolkata and has a processing capacity of around two lakh litres of milk a day. Keventer has achieved a top-three market position with its 'Metro' brand of pasteurized toned milk that is sold in pouches. Its other product offerings include ice-creams (Metro – The Dairy Ice Cream) and unsweetened curd (Metro Doi). These are primarily targeted at the value-seeker customer segment and enjoy sizeable market-share. In December 2018, Keventer launched 'Keventer Milk' – Ultra High Temperature (UHT) milk using Tetra Pak for providing consumers with safe and healthy milk without any chemicals/preservatives. (UHT technology sterilizes liquid milk by heating it above 135 degree Centigrade for 3 to 4 seconds thereby killing all harmful bacteria while keeping the nutrients intact. Following this, the milk is packaged into pre-sterilized, tamper-evident, six-layer Tetra Pak cartons which have a shelf-life of six months and does not require any refrigeration or boiling.) The Keventer Milk brand is marketed to most of the eastern and north-eastern states in India.

Corporate Entrepreneurship

R. Duane Ireland, Donald F. Kuratko and Michael H. Morris have identified Corporate Entrepreneurship (CE) as a process through which individuals in an established firm pursue entrepreneurial opportunities to innovate, paying attention to the level and nature of currently available resources (2018). Entrepreneurial opportunities are those situations in which new products (goods or services) can be sold at a price exceeding their cost of development, distribution and support. Corporate entrepreneurship strategy is an important path that can be used by firms to make it possible for employees to engage in entrepreneurial behaviours. CE helps a firm create new businesses through product and process innovations and market developments and fosters the strategic renewal of existing operations.

Advanced companies see the effective use of CE as a source of competitive advantage and as a path to higher levels of financial and non-financial performance. CE can be a source of competitive advantage at both the corporate and business unit levels. At the corporate level, CE helps diversified firms determine the mix for their portfolio of businesses and how to manage those businesses. At the business unit level, CE helps individual businesses develop and use one or more competitive advantages as a key means of implementing chosen strategies such as cost leadership or product differentiation.

Keventer's UHT Milk initiative – an analysis of Corporate Entrepreneurship

Keventer's role as a corporate entrepreneur in launching the UHT Milk to improve its competitive advantage and financial performance can be analyzed through the following tenets of strategic marketing:

Market potential – The UHT milk market has a huge potential to grow as UHT milk only accounts for 2.3 percent of India's organized sector, as compared to countries like China where UHT milk contributes to more than 60 percent of the total milk consumption. Consumption of UHT milk in India is currently at 1,500,000 litres per day, with 30 percent (450,000 litres) being consumed in eastern India at a valuation of Rs. 10 billion. The UHT market is growing at 23 percent annually. Keventer has a target of Rs. 2.5 billion by 2020 and expects to become the market leader in supplying UHT milk in eastern and north-eastern parts of the country. So after having established itself in pouch milk, ice-cream and curd categories, venturing into a new product line like the UHT milk business was a natural strategic progression for Keventer for building its competitive advantage.

Product – It includes three variants of milk – standardized (4.5 percent fat, thick and creamy – red pack), toned (3 percent fat, daily use – blue pack) and double-toned (1.5 percent fat, low calorie – green pack) in 1 litre, 500 ml and 200 ml packs. These are sold under the 'Keventer' brand instead of the 'Metro' brand, which has so far been the brand for its pouch milk, ice-creams and curd categories.

Price – The double-toned variant (green pack) is also available in 160 ml packs and is priced at Rs. 10 which is one of the most competitive prices in the present dairy market. Using contra pricing strategy, Keventer has set the price of this double-toned variant of milk lower than its other variants. At a business unit level it has thus chosen a strategy of price differentiation to develop its competitive advantage, which is distinctive from the pricing strategy of the other competitors in the highly competitive milk market.

Place – Upward movement of the milk in the dairy value chain to the retailers and consumers becomes the prerogative of the processing companies and the milk is transformed to a fast-moving-consumer-good (FMCG – Food) category in the process. By 2020 Keventer expects to gain 25 percent market share in eastern India by serving customers not only in West Bengal, Sikkim, Bihar, Jharkhand, Odisha and Chhattisgarh, but also in Assam and other north-eastern states, along with Bhutan. Increasing its distribution reach by foraying into geographically wider markets is possible for Keventer since UHT milk has a long shelf-life and does not require refrigeration when transported over long distances. As a corporate entrepreneur, focused penetration in selected markets is expected to enable it to achieve higher levels of financial performance.

Capacity-building – Keventer has established a state-of-the-art UHT milk plant at Barasat in North 24 Parganas district, in the outskirts of Kolkata at a cost of Rs. 1,500 million. It is the only plant in eastern India to produce UHT milk that goes into the Tetra Pak category. The plant is spread over an area of 55,000 square feet and equipped with the latest equipment. It has a processing capacity of 200,000 litres of milk per day. This capacity building is commensurate with its objective of doubling its income from dairy business, including ice-cream, to Rs. 8 billion from its current Rs. 4 billion over the next two years.

Backward linkages – For producing around 40,000-50,000 litres of UHT milk, Keventer currently sources the milk from 20,000 dairy farmers who are in a 100 km radius from its processing plant at Barasat. With the growth in demand of UHT milk, nearly 50,000 dairy farmers can be expected to come under its purview.

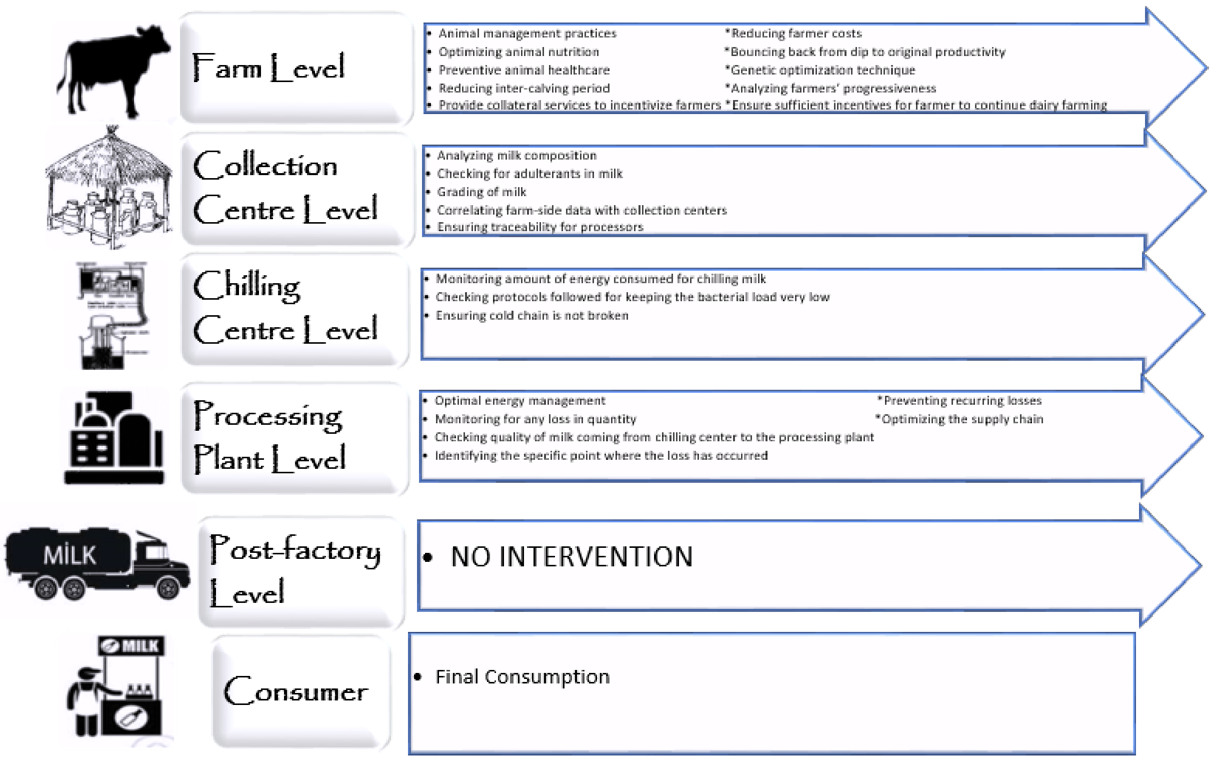
However, preliminary process-mapping and field-level analysis in Mini Dairy reveals that to bypass the impediments of sourcing small quantities of milk from unorganized, fragmented, individual dairy farmers, and to streamline an uninterrupted supply of milk for its processing plants, private players like Keventer source milk only through VLCCs like Mini Dairy, who work purely as their raw material (milk) suppliers for its processing plants. They do not interact with the milk producers (small dairy farmers) in the remote villages to provide them with support systems/assistance/facilities, nor do they develop any backward linkage with them to develop the existing value chain. They confine themselves solely to the role of a corporate entrepreneur – identifying opportunities for developing new products through process innovations, developing competitive advantages through implementing chosen strategies, designing go-to-market structures for greater market penetration and gaining higher levels of financial performance.

Business models of new-age entities in the dairy ecosystem for driving productivity in the value chain

The above-depicted value chain highlights the largely fragmented, unorganized dairy industry where the channel members majorly operate in silos with linkages only to their immediate backward and forward partners, in a myopic manner. A business model that effectively bridges this gap and takes a holistic approach to the dairy value chain by intervening at all its nodal points and providing technology solutions, will effectively create additional value in the dairy supply chain. It will benefit all the intermediaries by minimizing operational inefficiencies, improving milk productivity, enhancing profitability for all its members and ultimately offering better prices to the farmers for the milk that they supply. The business proposition of such an entity should be to create social impact while operating as a viable, for-profit organization.

The following study is based on in-depth interview that was conducted with Mr. Ranjith Mukundan, CEO, Stellapps Technologies Pvt. Ltd., in Bangalore to develop an understanding of the entity that assumes the role of an investible entrepreneur to drive profitability across the nodal points in the dairy value chain with its IoT solution platform (Figure 5). It explores the process through which a dairy technology-solutions company is creating measurable value for all stakeholders through technology interventions and digitization of the dairy supply chain.

Figure 5: Stellapps' interventions across the nodal points in the dairy value chain with its IoT solution platform



Initiative of Stellapps Technologies Pvt. Ltd. (dairy technology-solutions company) in addressing gaps across the value chain through technology interventions

Stellapps Technologies Pvt. Ltd. is an IoT startup in India that undertakes technology interventions at different levels of the dairy value chain to address issues such as low yield per animal, inadequate traceability of milk and its sub-par quality. Sufficient opportunity exists for aligning technology to agriculture in India. The agricultural fields are located in remote, rural locations from where the only way to capture data is through sensors. In villages, high quality expertise for animal husbandry is unavailable unlike the urban areas that have easy access to good quality experts. Cloud technology can form a reasonable substitute for lack of technical expertise in the remote village areas. Additionally, milk is homogeneous and needs to be monitored because it is the most perishable produce. Using technology in dairy farming can bring traceability and has a very significant role to play in the value chain.

Stellapp's clients are the dairy enterprises (e.g. Amul – cooperative, Heritage Foods Limited – private sector) who pay for the product and the solution services. These organizations have established milk procurement networks for over fifty years. Stellapps does not sell their solutions/services directly to the farmers who are the end-users in the system by being a part of the value chain. Their business model is B2B2C and not B2C or only B2B because though the service solutions impact the farmers directly, these are rendered only through the value network of the client.

Stellapps has designed both hardware and software platforms. (In 2018, it received the "Top Innovative Company (Small) in Manufacturing" Award from the Confederation of Indian Industry.) Its applications include SmartFarms (for milk production), smartAMCU (for milk procurement), ConTrak (for cold chain), MooKare (animal insurance product) and AgRupay (dairy farmer wallet). It acquires data from sensors that are embedded in animal wearables, milk chilling equipment and milk procurement peripherals. Using cloud computing the data is analyzed and the outcome is forwarded to various stakeholders over low-end and smart mobile devices. Applying IoT into the nodal points of such a vertical platform has helped Stellapps to penetrate the market faster and provide additional value as it is the product suppliers as well as the support system for the entire stack across the supply chain. This method is more effective than bypassing the dairy enterprises and approaching the individual dairy farmers directly.

Stellapps renders all the services mainly to the enterprises, but the collection center in-charge and the extension team of the dairy operator help in interpreting the data and communicating the same to the farmer. The farmer is also given direct access to the data but even if it is actionable, he may not have the entire context in how to optimally use the data. The intermediaries, who have undergone training from Stellapps and are slightly more advanced than the average farmer, are able to better render this function by explaining to the farmers the impact of the data (e.g. if they do not feed their animals a certain feed, they will lose Rs. 1000/- next week). Handholding the clients through the farmers by explaining how to use certain technology, supporting the farmers by taking into account the local culture and language, etc. requires more focus on the local touchpoint. So Stellapps follows a 'train-the-teacher' module with the collection center in-charge and the extension team of the client, in the local language for the best outcomes.

Broadly four benefits are being provided by Stellapps through this process:

a) Helping improve the yield from animal by better breeding mechanisms.
b) Reducing cost by ensuring that better quality milk is collected without any adulteration.
c) Improving quality by working on traceability.
d) Increasing convenience by letting the consumers know how the supply chain is working.

Intervention at the farm level

Stellapps can collect two data streams from the farms – the variable data stream that is captured through censors and the offline data stream for data that cannot be captured through censors (e.g. antibiotic injection schedules for cows and ration balancing for animal nutrition). Farm level interventions provide advice to farmers on preventive health care of animals, optimal breeding management, etc. Managing aspects such as health, vaccines, feed, using local forage like Azola (algae which grows in water and is good for a cow) instead of expensive off-the-shelf proteins which shoots up the costs, feeding bypass fat at the right time and intervening at the right phase of the lactation cycle results in optimizing the nutrition and bring down costs for the Indian dairy farmer who has on an average 4-6 animals.

Productivity can be improved significantly by firstly inculcating animal management practices to reduce inefficiencies and thereafter focusing on genetic optimization techniques. Simple management practices like giving the right feed, treatment, making the animal drink water, making them less stressful, not tethering them all the time helps Stellapps to significantly raise output per animal. Bouncing back from a dip to original productivity levels as fast as possible in case of disease outbreaks (e.g. foot and mouth disease) is important and Stellapps provides those solutions to the farmer by making him aware of the right feed that is required to be given to the cattle at the right time. This helps the cow resume its original productivity level much sooner than if the farmer had continued with the traditional feed. Also, till date the focus by veterinary doctors in dairy farms has been on curative aspects of animal sickness and not on preventive healthcare. Stellapps' intervention in these areas enables doctors to prevent animals from falling sick as compared to only treating sick animals, by using algorithms on data collected from the villages, which helps to improve animal productivity and reduce costs. Once the animal management issues are addressed, breeding attains priority. The inter-calving period is very long in India and it is advisable to bring down the period of dryness to 360 days. There is no ear-marked season for calving because of artificial insemination. Optimally in a herd of 4-6 animals, throughout the year at least 70 percent is expected to lactate as otherwise the income for the dairy farmer becomes uncertain.

Ancillary services to farmers at the farm level

Stellapps analyzes data of the farmers to understand how progressive a farmer is. If the farmer's productivity shows an increasing trend and he follows the vaccination and feeding protocols of the animals properly, then the farmer is classified as being more progressive. Stellapps gives fin-tech services to such farmers who have better productivity and higher ability to pay, and are psychometrically inclined to pay market interest rates. It lets the farmer get access to organized lending from banks and insurance packages with better rates than local money lenders, who charge abnormally high rates just because the farmers are not considered credit-worthy. Access to such collateral services better incentivizes these farmers and ensures that they have sufficient incentive to stay in dairy. Throughout the value chain it creates a positive tug for the farmers to move to the next level. So 3-4 animal farmers are encouraged to grow to the level of 5-6 animal farmers.

Intervention at the Collection Center level

Once the milk comes to the collection center the data is collected at an aggregated level. Grading of milk is done by analyzing milk composition (fat percent and SNF) along with adulteration checks (water, contaminants like urea, etc.) that determines the payments to the farmers, which in turn incentivize them to produce better quality, unadulterated milk. The farm-side data is correlated with the data from collection centers for traceability and to ensure that the milk collected from injected cows in the farm is segregated and not mixed with the rest. Premium dairy processors like Ferrero Rocher demand unadulterated and traceable milk that is fulfilled through Stellapps' farm-side interventions in segregating the milk.

Collection centers are very low-cost areas which collect 100-200 litres of milk each. With half a million collection centers spread across remote villages in India, providing for laboratory equipment in each collection center is a very expensive proposition. So Stellapps uses a simple, low cost and affordable cloud-based gadget system that can do artificial detection so that the operations at the collection center becomes affordable.

Intervention at the Chilling Center level

At the chilling centers Stellapps' interventions include monitoring the amount of energy that is consumed in chilling the milk and protocols that are followed in keeping the bacterial load very low. This is a necessity as the consumers who are willing to pay a premium require to know that the cold chain is not broken and the milk quality is of the specified standard.

Intervention at the Processing Plant level

Further up the value chain, in the processing plant the interventions address issues related to optimal energy management, checking the quantity of milk coming from chilling center to the processing plant, monitoring for any loss in quality and quantity. If any gap is detected, then the focus shifts on identifying the specific point where the loss has occurred in order to prevent it from occurring again. Such methods help in optimizing the supply chain.

Intervention at the Post-factory level

Post-factory intervention has major executional challenges for which it has not yet been taken up by Stellapps. Often retail outlets do not have cold chain facilities and after the milk is brought to the retailer the bacterial load in the milk increases. With more traceability the diary sector can market the milk as a premium segment product that can drive consumers to pay more.

Conclusion

The study identifies the value chain prevalent in the dairy industry, analyses the roles of the intermediaries and maps the major impediments existing within it. India has a large number of fragmented, marginal dairy farmers who exist in a subsistence level and do not have access to the most basic pre-requisites for producing quality milk. Hence, to consider these small farmers as future users of innovative technologies in dairy farming may be too far-fetched and unrealistic at the moment. This is because there is lack of awareness and consequently very little demand from those in the fields who can use data to take decisions and improve productivity.

However, as the study has ascertained, farmers' adoption of technology is possible when they are aggregated in collective efforts by cooperatives, producer groups, private enterprises and sufficient handholding is provided to them through the process. Owing to the remoteness of villages, sufficient opportunity exists for using sensory technologies in the farm levels. There are a large number of technologies that focus on optimizing cost efficiencies, improving productivity and traceability in the system; however, to gain widespread acceptability and usage among the farmer groups, an innovation that is easy to use, does not entail complicated technology, and is not cost prohibitive would have a higher chance of success.

As is evident, the country already has an adequate number of engineers with appropriate Information and Communications Technology knowledge, competencies and skillsets to develop dairy solution technologies. However, a favorable policy environment by the

Government will further encourage dairy startup ecosystems, complete with incubators, aggregators, venture capital funding, networking platforms and training facilities. Also, sufficient safeguard measures to protect the intellectual property that is developed, will boost future investments in innovative technologies in the sector.

Though farm-level technological interventions are still at a nascent stage in Indian dairy farms and may take several years before the average farmer operates in a tech-enabled farm, they are at the heart of the processes as they produce the milk and any improvement in the value chain ultimately gets back to the farmer through better rates and better market linkages.

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How feasible is the harvesting apples by robot?

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Abstract

The apple production requires intensive labour use in New Zealand like elsewhere. Labour shortage for harvesting is jeopardizing the competitiveness and sustainable production of apples. The shortage of skilled labour together with increasing labour costs, health and safety concerns, and unpredictable working regulations, have led the industry participants to become motivated in seeking alternative solutions to lessen the current dependency on labour force. This study examines the feasibility adoption of a robotic harvester for apples, using net present value (NPV) analysis as the base model to compare the investment decision under certainty to either purchase a robotic harvester to deal with the labour shortage or to completely use manual labour. The model is constructed based on two key factors, orchard size and apple variety. Using this type of model, the outcomes and impacts on various elements in adoption of a robotic harvester; the number of robots, the harvested and unharvested areas by robot, and the number of full time equivalent (FTE) labours, can be quantified. The outcomes show a linear increase in the studied elements across different orchard sizes and apple varieties. Performance factors of robot, the harvest speed and the harvest efficiency, are used to measure the sensitivity on the studied elements. Outcomes of the sensitivity analysis show that increasing the harvesting speed while keeping the harvest efficiency constant result in the reduction in the number of robots, the FTEs, and the unharvested areas; increasing the harvest efficiency while keeping the harvest speed constant increased the number of robots and reduced the FTEs and the unharvested areas.

Keywords: Apples harvesting robot, labour shortage, net present value (NPV), sensitivity analysis.

Presenters profile

Morteza Ghahremani is a second year PhD student in Agribusiness at the School of Agriculture and Environment, Massey University. Prior to commencing his doctoral studies in New Zealand, he earned a Master’s degree in International Economics and Commerce from Seoul National University in South Korea. His current research is focused on bio-economic modelling of New Zealand agri-food systems. In particular, Morteza is looking at the economic feasibility of adoption of robotic harvesting technology in the New Zealand apple industry by implementing various scenarios.

Precision Livestock Farming technologies – at what cost? An *ex ante* analysis of technologies and digitalisation in grazing systems

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Abstract

The development of precision livestock farming (PLF) technologies for application in extensive grazing systems is rapidly evolving. Technologies that allow the autonomous monitoring of pasture growth, feed intake, animal condition and liveweight, and thus support real-time decision making, promise to improve the efficiency, productivity and sustainability of livestock farming. However, such technologies as a complete package do not yet exist and the question of economic impact at the farm system level remains unresolved. Other potential benefits, including the impacts of technologies on the externalities of production, such as reductions in net GHG emission intensity and other pollutants, also remain unresolved.

To determine the net benefits of autonomous PLF for extensive grazing systems, an *ex ante* analysis was undertaken using the Sustainable Grasslands Model (SGM), a dynamic bio-economic model that simulates livestock production systems at the mechanistic level and integrates the results into a whole farm system framework. The SGM has been calibrated using data from Rothamsted Research's North Wyke Farm Platform and applied to a typical lowland sheep meat production system in the UK. This study compares current management practice to a complete 'smart' system that maximises the possible benefits from autonomous PLF in real-time. It identifies the marginal productive, environmental and economic benefits from the full adoption of the technology package. Then, using a target cost approach, the identified economic benefits define the maximum permissible capital and implementation costs for a farmer adopting the technology based on a target rate of return.

Presenters profile

Prof Karl Behrendt joined Harper Adams University in January 2018 and is Director of the Global Institute for Agri-Tech Economics. His focus is on working with industry and other research institutions to provide economic intelligence and agri-tech solutions for UK and global agriculture and value chains. His core discipline is in the area of bioeconomic modelling of agricultural systems and decision support for farmers. Prof Behrendt is currently undertaking research into the economics of precision livestock farming, precision landscape management, robotics in agriculture, the international comparative analysis of beef and sheep production systems, and improving grassland policies and payments for environmental services in China and Mongolia.

Profit maximization in soybean (Glycine max (L.) Merr.) using variable rate technology (VRT) in the Sárrét Region, Hungary

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Abstract

Variable rate technology (VRT) in seeding (VRS) and variable rate application (VRA) of fertilizers aims to treat within-field differences occurring in agricultural lands. VRT in maize, winter wheat, and sunflower is widely applied in Hungary, however, for soybean (*Glycine max* (L.) Merr.) experiments are still not widely available. The objective of our work was to investigate the effect of VRS and VRA of fertilizers on the profitability of soybean production in a 43.1-hectare trial field. The trial is located in the Sárrét Region, Hungary. Management zones were determined according to earlier yield maps, satellite imagery, and earlier Topcon CropScan measurements. The applied treatments were: 1, varying only seed rates: 525-615 k-seed/ha; 2, varying nutrient rates: N: 32-54 kg in the form of Calcium ammonium nitrate (CAN 27%N), P: 84-116 kg in the form of Diammonium phosphate (DAP 18%N:46%P_2O_5), and K: 7-80 kg potassium (60%K_2O); and 3, varying seed and fertilizer rates as well. Base fertilizing was carried out on 27 March 2018. Seeding was carried out on 25 April 2018 using 15 cm row spacing. Top-dressing (FitoHorm Szója, 5 l/ha) and weed control (Corum herbicide, 1.9 l/ha) were carried out uniformly on 30 May 2018. For profit calculations all expenses were calculated (cultivation, soil sampling and analysis, seeding, top-dressing, herbicide treatment, nutrient replenishment, and yield mapping) as inputs and the yield actual selling price as income. The highest profit was reached by applying VRS and VRA at the same time. Untreated control resulted in a significantly lower profit. We state that the application of complex site-specific variable rate technology resulted in higher profit than individual VRS or VRA treatments using extra input materials. We also state that a reference site-specific technology for soybean treatment was also found, which can help advisors in the region in the future.

Keywords: VRA, VRS, soybean, profitability

Presenters profile

Dr habil Gabor Milics, PhD, Geographer, Precision Agriculture Advisor, received his PhD from University of Pécs. Currently he is working at Széchenyi István University/University of Győr, as an associate professor. His research interest is GIS and Remote Sensing applications in Precision Agriculture. Currently he is the country representative for Hungary in ISPA. He is also the founding president of the Hungarian Society of Precision Agriculture. Dr Gabor Milics is the co-organizer of the 13th European Conference on Precision Agriculture, which takes place in Budapest, Hungary in 2021.

Jakab Kauser is a young farmer and consultant on precision farming in Hungary. Graduating form Szent István University in Gödöllő, Hungary he started his own business in the advisory sector. In the last several years he gained more knowledge in plant protection and precision agriculture in the practice (monitors, yield mapping systems, nitrogen sensors, UAV applications, GIS applications, etc), which experience is applied in his own consulting practice (K-Prec Ltd.). He started his PhD studies at Széchenyi István University/University of Győr recently, focusing on management zone delineation and economy of precision farming implementation.

Introduction

Variable rate technology (VRT) in seeding (VRS) and the variable rate application (VRA) of fertilizers aims to treat within-field differences occurring in agricultural lands. With the appropriate farm equipment, site-specific management can be carried out in order to define the most profitable treatment for various plants. The results of research on maize, winter wheat, and sunflower experiments are available regarding VRT in Hungary; however, results for soybean (*Glycine max* (L.) Merr.) experiments are still not widely available. In order to apply variable rate seeding, there are four basic steps to be followed: first and foremost, management zones have to be identified. *Management zones* are well suited for locating benchmark soil-sampling sites. Small, spatially coherent areas within fields may also be useful in relating yield to soil and topographic parameters for crop-modelling evaluation. Stafford et al. (1998) used fuzzy clustering of combine harvester yield-monitor data to divide a field into potential management zones. Management zones are usually based on soil types or yield maps proceeding from several years of data (preferably from similar plants), or general knowledge of yield or any other within-field differences (Gili, 2017). Management zone analysis provides spatial information on within-field differences (Fridgen et al., 2003). The second step is that the *seed rate* has to be determined. A standard recommendation when VRS is introduced in a field is to decide on three to four seeding rates with a reasonable difference. Due to their ability to compensate for stand differences, soybean crops provide high yield over a range of seeding rates. Seeding rates over the economical limit, however, add unnecessary costs and can lead to problems with diseases and lodging, consequently lowering profit. Because of the potential differences in seed size, soybean seed should be planted based on seeds/ha, not kg/ha. The effects of row spacing and seed rate on soybeans in the US have been investigated by De Bruin and Pedersen (2008). They stated that adaption of narrow-row spacing and seeding rates in Iowa could be used to reduce production costs and increase yield and profitability. Once seeding rates are determined for each zone, a *prescription map* has to be created. As a final step, the prescription map has to be *uploaded into a variable-rate controller*. The controller has to be calibrated and set for the required parameters and finally has to be set to *record* as-planted information.

Row spacing of soybean has changed over time. In the past wide-row spacing (76 cm) was preferred by growers; nowadays, narrow-row spacing is used in practice. Other than yield, the most important factor driving soybean row spacing practices is equipment and time management during the planting season. One of the key issues' growers must consider is whether the economics of their farm justify having a machine dedicated specifically to planting soybeans. In practice, it is practical to share soybean with other crop-planter equipment such as wheat- or corn-planters (Jeschke and Lutt, 2018).

Yield increase for soybean row spacing was reported by Bertram and Pedersen (2004). They found a 5% yield increase in 0.19 vs. 0.76 m rows in southern Wisconsin, an 8.7% increase in central Wisconsin, and a 9.6% increase in northern Wisconsin in a 3-yr study. Economic studies also reported advantages for narrower row spacing. Lambert and Lowenberg-DeBoer (2003) concluded that planting soybean in 0.19 m rows with a grain drill was more economical in annual corn–soybean rotation in the North-Central United States, based on a summary of studies showing a 4.8% yield advantage for drilled (<0.25 m rows) compared with 0.38 m rows.

Soybean's high yields are possible only when the crop's nutritional requirements are met. Mismanagement of nitrogen or other fertilizer application prevents a grower from achieving yield potential. Variable rate technology (VRT) can be used to vary seed and fertilization rates within a field. Fertilizer variations have strong effects on yield production. Soybean grains have a nitrogen content of 40%, therefore adequate fertilization of nitrogen is required for achieving high-quality yields. According to McKenzie (2017) nitrogen (N) fertilizer is rarely recommended in Canada for soybean, even if the soil test N level is low and it is the first-time soybean will be grown on virgin land. On the other hand, potassium and phosphorus variability highly affects production. Investigating phosphorus fertilization, Wittry and Mallarino (2004) reported better P fertilizer management applying VRA because it applied 12 to 41% less fertilizer compared with the traditional uniform rate fertilization method. On the other hand, McKenzie (2017) stated that recent research by the University of Manitoba has shown that phosphate (P_2O_5) fertilizer does not have a strong effect on soybean growth or yield.

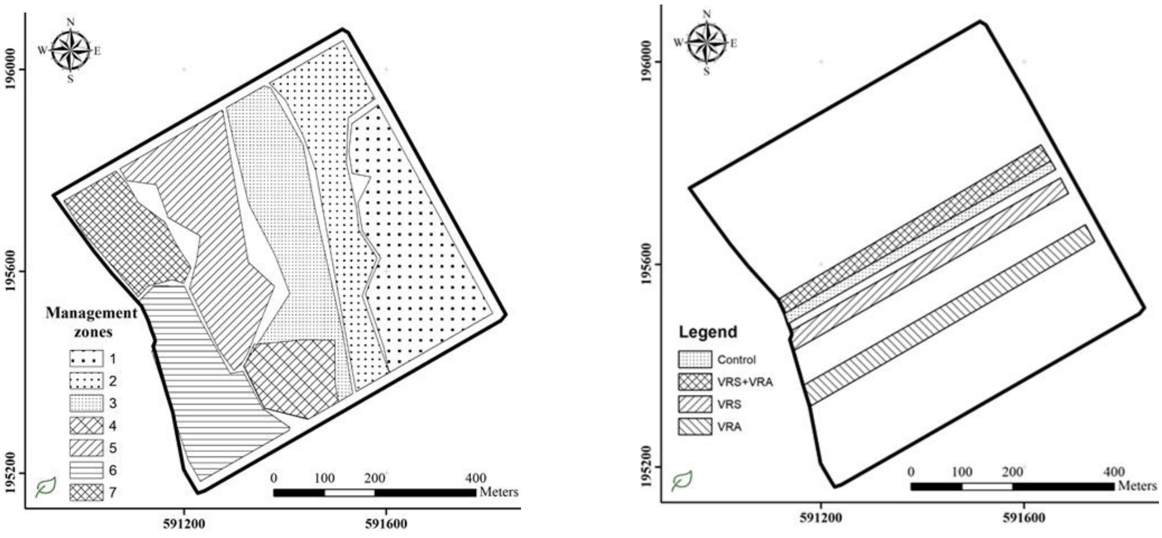
Methods

Instrumentation

Cultivation was carried out using a Fendt 936 tractor and a Lemken diamant plough, the seedbed was prepared with the same tractor mounted with a Farmet kompaktomat 850. For fertilizing a Fendt 720 tractor and Amazone ZA-TS spreader were used. Seeding was carried out by a Fendt 720 tractor and a Horsch Pronto 6DC precision seeding machine. Top-dressing and weed control was carried out by a Fendt 716 tractor equipped with an Amazone UX fertilizer. For harvesting, a Claas Lexion 660 combine harvester was used equipped with a TopCon YieldTrakk yield monitoring system. For control and data collection, a TopCon X35 monitor was installed in the machines.

Location

The trial is located in the Sárrét Region, Hungary. Management zones were determined according to earlier yield maps, satellite imagery, and earlier Topcon CropScan measurements. After autumn cultivation soil sampling and analysis were carried out in January 2018. Soil samples were collected from each management zone, defined by earlier experience and measurements (Fig. 1a.).



a) b)

Figure 1. Locations of the management zones (a) and the various treatments (b) within the trial field.

<u>Trials</u>

Various trials were carried out, such as the effect of top-dressing or bacteria starter treatment, however, in this paper focus is on the profitability of the technological variations of VRS and VRA. Applied treatments were: 1, varying only seed rates (VRS): 525-615 k-seed/ha; 2, varying fertilizer rates (VRA): N: 32-54 kg in the form of Calcium ammonium nitrate (CAN 27%N), P: 84-116 kg in the form of Diammonium phosphate (DAP 18%N:46%P_2O_5), K: 7-80 kg potassium (60%K_2O); and 3, varying seed and fertilizer rates (VRS+VRA) as well (Fig 1b.).

Base fertilizers (DAP and Potassium) were applied on 27 March 2018 with the recommendation rates determined by soil sampling, laboratory analysis, and the "K-Prec" Ltd. advisory system. N application was carried out on 20 April using the same advisory method (Fig 2., Tab.1.). The seed-bed was prepared on 23 April; seeding was carried out on 25 April. The row spacing was 15 cm. Seeding rate (Fig 3.a), CAN (Fig 3.b) DAP (Fig. 3.c), and Potassium (Fig 3.d) treatments were applied according to the experimental setup. Top-dressing (FitoHorm szója) was applied on 30 May in the amount of 5 l/ha. Weed control was carried out uniformly on the same date using Corum herbicide (1.9 l/ha). Expenses for each working task and input materials were calculated (Tab. 2.).

Fixed costs such as cultivation, soil sampling, and laboratory analysis, machinery for fertilizer application, top-dressing, weed control, harvesting, and costs for uniformly applied top-dressing material and weed control material were calculated for the whole field. Variable costs (fertilizers and seed) were calculated based on the size of the treatment units. All data was collected and uploaded into Topcon SGIS software. For income calculations yield was measured. Profit was calculated automatically by SGIS software for each management unit based on the collected and uploaded data. Moisture content was also registered, therefore the actual, comparable amount of dry yield for each unit was calculable. The actual market price for soybeans was EUR 322 /t.

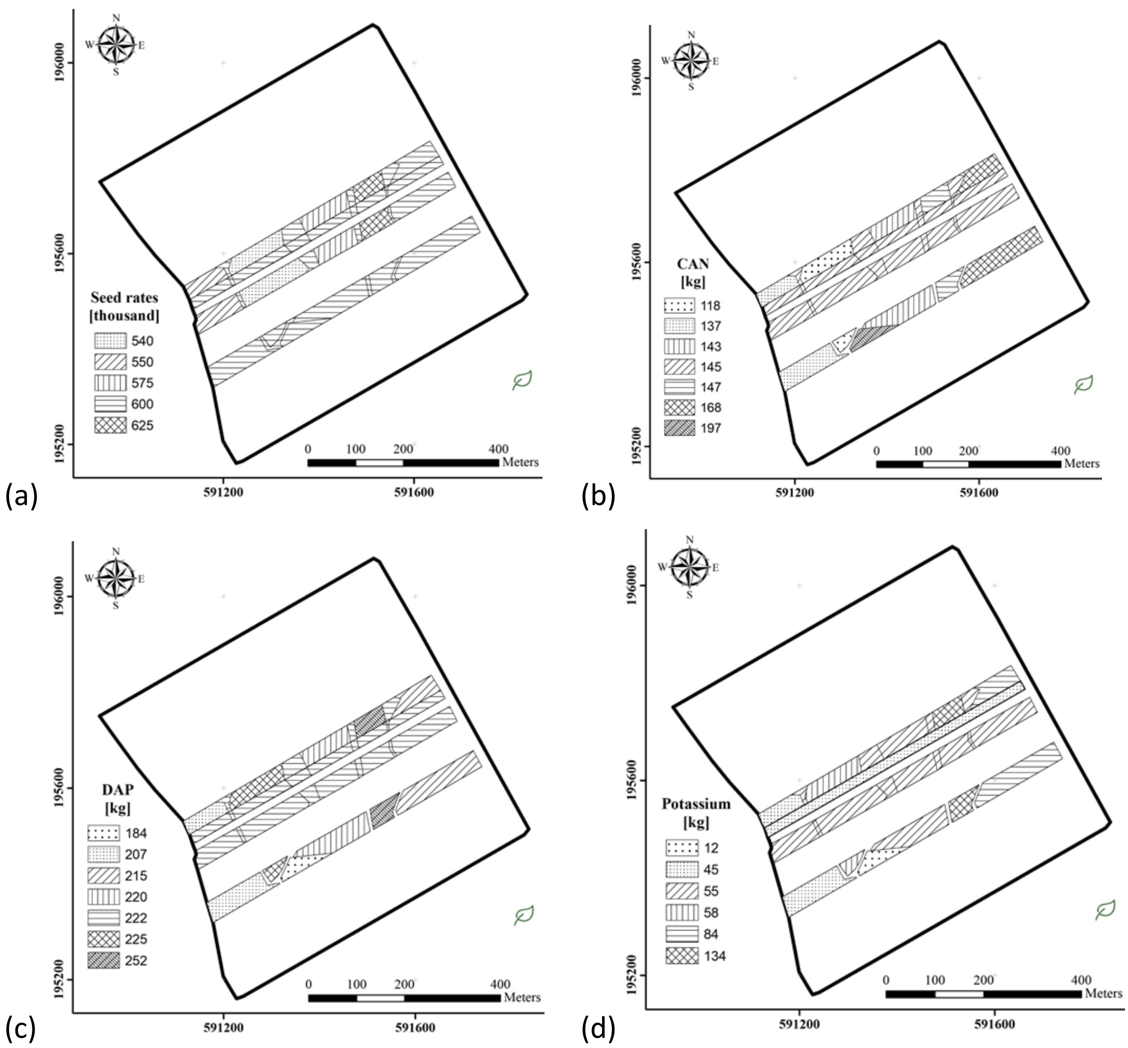


Figure 2. Amounts of variable rate applications in each experimental unit

Table 1. Fertilizer amounts applied in the experimental field

Management zones	1	2	3	4	5	6	7
Seed rate (in thousands)	600	625	575	575	540	550	550
DAP (kg)	215	252	220	184	225	207	222
CAN (kg)	168	147	143	197	118	137	152
Potassium (kg)	84	134	55	12	58	45	49

Results

The differences in costs for control, only VRS, only VRA, and VRS+VRA were relatively low, EUR 659.35, EUR 663.44, EUR 667.29 and EUR 664.26/ha, respectively (Tab. 2.).

The maturation of soybean differed, therefore moisture content of the harvested areas differed as well. The control zone was harvested with 15.19% moisture content, whereas the VRS zone moisture content was 15.9%. The VRA zone was slightly less, at 15.2%, and the driest zone was the VRS+VRA application, at 13.4%. The differences in moisture content resulted in variations in yield as well. The total productivity of each investigated zone is shown in Tab 3. As production was the highest in the zone where VRS and VRA were applied (4.86 t/ha), this zone produced the highest income as well (EUR 1,564); consequently, the highest profit (EUR 899.45) was realized here. Untreated control produced a significantly lower profit (EUR 704.83). Profit for the zones where only VRS or VRA was applied was even lower than the control zone's profit, EUR 598.86, and EUR 692.53, respectively.

Table 2. Expenses of soybean production in EUR at the investigated farm (calculations are related to 1 ha).

Expenses	Control	VRS	VRA	VRS+VRA
Soil sampling[1]	10	10	10	10
Cultivation+seed bed[2]	143.75	143.75	143.75	143.75
Machinery[3]	65.63	65.63	65.63	65.63
Top-dressing	20.31	20.31	20.31	20.31
Weed control	65.63	65.63	65.63	65.63
Harvesting	68.75	68.75	68.75	68.75
DAP[4]	70	77.35	74.55	77
CAN[4]	23.4	23.24	24.54	22.59
Potassium[4]	15.19	15.19	17.44	18.56
Seed[4]	176.7	173.6	176.7	172.05
Total	659.35	663.44	667.29	664.26

[1]Including laboratory analysis and advisory services
[2]Cost of labour (machinery, fuel, etc.)
[3]Cost of machinery for seeding, base fertilization, top-dressing and weed control
[4]Expenses are calculated for the treatment unit

Table 3. Calculation of the profit of soybean production in EUR at the investigated farm (calculations are related to 1 ha).

	Control	VRS	VRA	VRS+VRA
Total Costs (EUR)	659.35	663.44	667.29	664.26
Moisture (%)	15.3	15.9	15.2	13.4
Yield* (kg)	4,238.24	3,921.7	4,224.67	4,858.21
Income (EUR)	1,364.18	1,262.3	1,359.82	1,563.74
Profit (EUR)	**704.83**	**598.86**	**692.53**	**899.47**

*Corrected amount of yield for the treatment unit

Discussion

Soybean is of high importance in Hungary as it is a valuable source of high-quality vegetable protein. Farmers practicing site-specific application are investigating ways to achieve best practices for soybean production. Research on variable rate technology and its adaptability in soybean production was carried out with the focus on profitability for variable rate seeding and variable rate fertilizer application. Calculations of profitability were carried out automatically with the help of Topcon SGIS software, which made it possible to easily collect the values for treatment units, even if there were more than 5 management zones within the area. Soybean planted in a 15-cm row produced a 3.9-4.8 t/ha yield, depending on the technology applied.

Applying variable rate technology to soybean production aimed to find the best technology and the most economical seed rate as well as fertilizer rates in the Sárrét Region, Hungary. The experiment was carried out by precision agriculture machinery; as-applied data collection was available for monitoring each piece of technology. The calculations clearly showed that applying variable rate seeding without variable rate fertilization or applying variable rate fertilization without variable rate seeding was even less profitable than the conventional (control) soybean production. We state that the application of site-specific variable rate technology as a complex solution results in significantly higher profit than the regular practice. We also state that a reference technology for soybean treatment was also found, which can be used in advisory systems in the future in the region.

Acknowledgements

The authors would like to thank K-Prec Ltd. and Szekeres Ltd. for providing the data and equipment for the research. This project was partly supported by the EFOP-3.6.3-VEKOP-16-2017-00008 project. The project is co-financed by the European Union and the European Social Fund.

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Autonomous Machinery: Where We Are in the U.S., Where We Are Heading, and Economic Methods for Evaluating Profitability and Risk

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Abstract

Over the years, the dominant trend in agricultural machinery has been toward the use of larger sizes of conventional equipment in U.S. crop production. Autonomous tractors provide a potential alternative to the growing problems with larger agricultural machinery, which could lead to a paradigm shift in the structure of agriculture. The implications of autonomous machinery could be profound and will most certainly encompass a variety of disciplines. The potential economic benefits of utilizing autonomous machines are numerous and could develop into a more profitable approach to production agriculture. Autonomous machinery outside of agriculture is now front and centre in mainstream U.S. media from large automobile manufacturers and ride-sharing companies. However, it has been only recently that autonomous machinery has been successful in operating in large-scale grain crop production. The questions become "Can autonomous machinery compete with conventional farm machinery in the production of grains in the U.S.? Also, what will the design of autonomous machinery look like moving forward and how can economists aid engineers in the development and successful commercialization of autonomous machinery in U.S. commercial agriculture?"

There are three general configurations of autonomous machinery in various phases seeking the end goal of successful commercialization and adoption by U.S. producers. Those three types of autonomous machinery are (1) small, one row autonomous robots conducting a single task, (2) medium-sized autonomous machines (<50 hp) capable of attaching small width implements, and (3) large autonomous machines similar to those in commercial grain crop production. Recently, agricultural machinery manufacturers Case IH and New Holland have both released their version of autonomous tractors that are large and similar to those in commercial grain crop production. Regardless of which path leads to commercialization and adoption, the potential economic benefits of utilizing autonomous machines are numerous and could develop into a more profitable approach to production agriculture.

This presentation will discuss a variety of topics including the status of autonomous machinery in the U.S. and the opportunities for mathematical programming models to assess both the economic feasibility and the potential for reducing production risk using autonomous machinery in U.S. grain crop production. Furthermore, this presentation will identify a host of economic issues about each of the three types of autonomous machinery mentioned above to foster collaborative efforts to address the lack of research in these areas (e.g. economies of size with small and medium machines, environmental quality with small and medium machines, and legal implications and farm safety with large machines). Finally, extension/outreach methods are presented to communicate research results to key stakeholders impacted by autonomous machinery.

Presenters profile

Dr. Shockley is an Assistant Extension Professor and Farm Management Specialist within the Department of Agricultural Economics at the University of Kentucky. His areas of expertise include the economics of precision agriculture technologies, post-harvest management, machinery management, the economics of soil quality, and poultry economics. His research on the economics of precision agriculture and robots spans the past 15 years publishing his work in renown precision agriculture journals and presenting results nationally and internationally, while educating producers around the U.S. on the proper techniques for evaluating the profitability of precision agriculture technologies.

Big Data, Blockchain, and Autonomous Machinery can they be fully implemented before address broadband access?

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Abstract

Paradigm-shifting technologies such as Big Data, distributed ledger technology, and autonomous machinery are currently being researched and implemented worldwide. One potential barrier to full implementation and value realization was these technologies is lack of broadband connectivity especially in rural areas were farmers produce grain. This presentation and manuscript focuses on broadband connectivity across the globe. Specifically within the United States, broadband connectivity impacts on both big data utilization and on the agricultural industry at large are being evaluated. In the absence of broadband connectivity in general and wireless data transfer in particular, the benefits of big data, telematics, precision agricultural services, blockchain implementation, and autonomous machinery are limited. In addition to constraining the profitability of agricultural firms, lack of broadband connectivity limits the adoption and efficiency of precision agricultural technologies that rely upon near real-time connectivity. Additionally, these precision agriculture technologies are the primary data collection methods populating big data systems. Recently passed legislation such as Iowa's "Connect Every Acre" bill signed into law in June 2015, demonstrates the recognition of this topic by policymakers.

Many producers currently employing precision agriculture technologies without access to high-speed wireless connectivity are utilizing cellular connectivity to transfer data or are still utilizing manual data transfer. Current 4G cellular connections only allow up to a 10 Mbps download speed, and upload speeds that range from 2 to 5 Mbps. Given that 1) most data generated from within-field precision agriculture technology needs to be uploaded rather than downloaded and 2) upload speeds are substantially slower than download speeds, are current connectivity speeds fast enough to move information so that real-time decisions can be made? For some types of data, e.g. machine diagnostics, planting prescriptions, and the like, current speeds offered are probably adequate. However, yield data and specifically imagery data may require connectivity speeds more than what the telecommunications industry currently offers especially for real-time utilisation. More importantly, these connectivity requirements may not be a cost-effective method of data transfer.

Key Questions to Address

What upload and download speeds are needed to allow producers to move data real-time?

What data needs to be moved real-time?

Where are we at with the broadband buildout?

Presenters profile

Tyler Mark is an associate professor of production economics in the Department of Agricultural Economics at the University of Kentucky. His applied research interests include digital agriculture, simulation methods, broadband availability in rural areas, precision agriculture, precision dairy, dairy policy, renewable energy feedstocks, and hemp economics. Funded projects through USDA-NIFA, USDA-RMA, NSF, and industry partners provide the resources needed to investigate the profitability of Kentucky farmers, broadband internet's impact on precision agriculture data transmission, the economic aspects of hemp production in Kentucky, dairy policy in the South-eastern United States, and the development of the Kentucky economy.

Productivity trends and drivers in global agriculture: Could the UK match up in a post Brexit world?

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Abstract

The analysis in the paper focuses on global trends in total factor productivity (TFP) growth and some of its key components and drivers. The relative performance of the UK in relation to many key countries with globally important agri-food sectors, either or both as exporters and or importers of agricultural products, and as potential targets of its future UK post-Brexit strategy are examined. Two approaches are explored in order to gain some insights into productivity growth and its measurement: the decomposition output growth through the contributions of growth in land, labour, capital, material inputs and TFP, and modelling output growth to identify the significant contributing variables. Finally, the challenges that the agricultural sector of the might face as a consequence of its proposed UK post Brexit agricultural policy (if and when it might happen) for its productivity are considered and some conclusions regarding the relevance to future agri-technology developments are outlined.

Presenters profile

Brian is Professor Emeritus of Agricultural and Food Economics since his retirement in 2013 and formerly Director of International Policy at Harper Adams University. He was President of the Agricultural Economics Society in 2015-16.

His main areas of research interest and publications experience are in international agri-food trade, trade policy and its market and environment impacts, international competitiveness, demand analysis, marketing and supply chain management over a wide range of agricultural and marine commodity and food sectors and regions including Africa and China. He has extensive international consultancy and advisory experience with business, government and international organisations, and currently is a core member of Defra's Economic Advisory Panel.

I. Introduction[1]

Not for many years has the UK agricultural sector faced such uncertainty about its long-term future with a number of possible policy–directed paths depending on the outcome of the Brexit negotiations within Government and between Government and the EU27. The policy spectrum at the time of writing embraces the extremes of no-change (Remain) to full policy autonomy as in the Agriculture Bill (Hard Brexit). This paper focuses on one key dimension of the underlying issues that will be a common thread in the future wellbeing of the sector, notwithstanding the final policy outcome, namely "is and will the sector be fit to compete and meet the challenges of a competitive international agri-food trade environment within or

[1] This section draws on a recent article by the author – *UK Agriculture: future challenges in the global agri-food trade arena*. Land Journal Oct-Nov 2018, Royal Institution of Chartered Surveyors (RICS). pp. 16-19.

outside the EU?" One might further add the rider given that the future policy direction for a UK as a third country contains some potentially mutually conflicting objectives to: -

- Improve farming productivity (sustainable intensification?)
- A new environmental land management system (public money for public goods)
- Maximise trading opportunities (increasing exports is a Government priority).

As all three primary objectives thus have the potential either beneficially or detrimentally to impinge on UK agricultural productivity.

II. Agri-food sector productivity-concepts and measurement

We generally measure productivity in terms of outputs and output change relative to inputs, in other words how efficiently an industry/sector transforms inputs to outputs. The key measure used by economists is called total factor productivity (TFP). To simplify, this essentially measure the changes in the levels or values of outputs relative to those of inputs. In the case of output from agriculture as a sector, we measure its aggregate value of output relative to the aggregate value of multiple inputs. TFP is normally expressed as the ratio of Output(s) to Input(s).

Making cross-country comparisons from national data is however fraught with difficulties, in that differing methodologies and definitions of inputs and outputs are common. The USDA has compiled a dataset[2] across for the World average and 187 countries based on the work of Keith Fuglie. It contains raw, indexed and growth rate data for output and key inputs based on FAO statistics[3], supplemented where appropriate and available by national government estimates together with estimates (10-year averages) of factor cost shares. The dataset which originally covered the period 1961-2010 has been recently updated to 2015. This therefore affords an opportunity to update the global agricultural TFP estimates beyond the immediate financial crisis of the period 2007-2008 presented in Fuglie (2015)[4], and also to make cross country comparisons with the UK given that the Fuglie article focused on regional and sub regional TFP and economic aggregates of industrialised, developing and transition economies.

The relevant country variables used in this paper and defined more fully in the dataset are as follows:

- Agricultural output: gross agricultural output at constant 2004-2006 average international prices.
- Factor shares: a compilation of input cost shares derived from a range of studies and expert views and defined as 10-year averages for the periods 1981-90, 1991-2000, 2001-2010; 2011-2020(sic)
- Agricultural inputs: total input growth rates and indexes for each country with quality adjustments for animal feed, farm machinery capital and land are applied. Specifically, they include:
  - o Land – agricultural land in hectares of "rainfall crop equivalents".

[2] Data source: USDA (2018) https://data.nal.usda.gov/dataset/international-agricultural-productivity
3 FAO Statistics http://www.fao.org/faostat/en/#
4 Fuglie K (2015) *Accounting for growth in global agriculture*. Bio-based and Applied Economics 4(3): 201-234.

- o Labour-number of adults economically active in agriculture
- o Livestock capital – end of year inventories of livestock held on farms in cattle equivalents weighted according to species
- o Machinery capital – total stocks of farm machinery in 40-CV tractor equivalents for 2 and 4 wheel tractors, combines and threshers
- o Fertilizer- metric tonnes of NPK consumption.
- o Feed- total ME in animal feeds from all sources
- o Fertilizer and feed constitute Materials – effectively variable inputs.

The selected countries for analysis were some of emerging BRICS economies -Brazil, China, India and the developed economy countries UK (GBR), USA and Australia. All are potential UK post Brexit targets for future Free trade agreements.

Some caveats are worth voicing not only in relation to the methodologies employed, but also in underlining the nebulous concept of productivity. Clearly there is a vast range of inputs not included in the dataset-for example some output such as cereals or legumes and their bi-products are utilised for intermediate consumption in livestock production; manures supplement artificial fertilisers etc. On might also question whether change in stock of machinery capital accurately captures both the quality of the equipment (not simply related to engine capacity) and the cumulative impact of such changes can have on output and productivity. Economies of size arising from farm enlargement and changes in farm size distributions will also inevitably impact on productivity if "fixed resources" can be spread over more land in cultivation. Post 2015, there have been major advances in applications of robotics, IT, plant breeding and GM which will enhance productivity through greater precision, yield growth, waste reduction, all of which feed into inputs quality and hence TFP. We must also recognise that output growth rates are susceptible to weather and climate change, irrespective of inputs applied. Whilst gross output at constant prices reflects changes in physical output, abstracting from exchange rates, international market conditions and agricultural policies, they nevertheless have a bearing on farmer output decisions, either encouraging or discouraging capital investment and resource deployment which will have longer term implications for productivity. Finally, there is a question as to whether externalities such as environmental costs arising from farming practices should be incorporated into the output calculation to better reflect the adverse direct effects of factor use. So, in conclusion, we have a number -TFP -which is dimensionless and permits comparisons between countries on a consistent base of data, not only on the combined use of factors of production, but their individual contributions to be derived (partial productivity indices). It is the best we have at present.

TFP is not an observable variable, but a theoretical or conceptual variable derived from observables. Appendix A.1 sets out the theoretical background to the methodologies employed in this paper, in which the individual contributions of classes of major inputs, land, labour, capital and materials (i.e. variable inputs) to output growth are derived. Two approaches are adopted utilising the same dataset, viz. decomposition of output growth and econometric modelling of growth, from which the measure of TFP growth in principle can be determined, and some indications as to those farm-related factors most influencing output variation and hence TFP by derivation.

The cost shares and factor impacts on output by econometric modelling are both presented in sections III and IV. First, the long-term trends in world and countries' factor growth are examined in relation to TFP for the entire period 1981-2018 in section III, and as shown in Figs A.3.1 of Appendix 3 and models 3 in Appendix 2. The modelling analysis in Appendix 2 also examines two subperiods 1981-2000 and 2001-2015 (models 1 and 2 for each country or region) to highlight any pre and post millennial changes and to provide a broad comparator to the subperiods in section IV[5]. A comparison of the two approaches is also presented and discusses the estimated outcomes for the world and UK (GBR). Section IV examines the cost shares decomposition by 4 subperiods (defined by the factor share periods in the USDA database viz. 1981-1990, 1990-2000, 2001-2010 and 2011-2015 as a finer tuned analysis of changes in output and TFP growth composition.

III. Long term trends in world and country productivity 1981-2015.

Figures A.3.1. show long term factor trend average annual growth rates over the period together with those of output and TFP. World factor growth rates were positive with those for materials (fertilizer and feed) around 1.5%pa. However, factor growth rates in the UK with the exception of fertilizer and feeds were negative. World output growth averaged 2.2%pa and TFP 1.4%pa. In contrast, in the UK, gross output and TFP were lamentably small, with the former hovering around zero, and the latter under 0.5%, both well below the global mean and all of the selected countries.

Models 3 in A.2.1 (World) and A.2.6 (UK) identify the key drivers of output growth predominantly as materials., although in Brazil, UK, and Australia, livestock capital was also a statistically significant driver of output growth, machinery capital in the USA (negatively, especially since 2001. Labour was only significant in Australia (inimical to output growth, though positive in Brazil post-2001.

Table 1 overleaf compares the outcome of the modelling and factor cost decomposition approaches in describing and explaining output growth and TFP. By virtue of the fact that all the growth weighted cost shares of all inputs are included in the output growth equation, we are able to derive the" residual" TFP growth rate given an estimate of output growth. For world output growth, materials were the most significant contributor to output 0.36%pa followed by labour 0.18%pa. All factors contributed 0.86%pa of the average output growth rate of 2.2%pa[6]. Hence TFP made up the remaining 1.22%pa. The modelling only identifies materials, i.e. variable inputs statistically as statistically significant determinants of output growth with the constant significant also at 1.2%. This would appear to support the hypothesis that it reflects TFP contribution, with other capital, land and labour factors insignificant in affecting annual variation in output growth and their contributions reflected in TFP itself.

The decomposition of UK output growth is interesting and reflects the negative growth rates of all inputs except materials. The negative overall allocated factor cost growth contributions

[5] Modelling analysis of the 4 subperiods would have insufficient observations for each subperiod to provide reasonably robust model coefficient estimates of the factor growth impacts on output growth and to derive the associated TFP growth rate estimates. Indeed, the author feels even the number of observations for the 2 sub-periods is pushing the limits of reliable coefficient estimation given the time series techniques required (and even for OLS). Hence comment above is limited to the full data series Models 3 for 1981-2015.

[6] Unsurprisingly as they are the growth weighted input cost shares.

to output growth exceeded in absolute terms the growth in output, thereby producing a positive TFP of less than 0.4%. Estimation of the output growth equation identified only 2 statistically significant facts -livestock capital and materials inputs, which were dominant. The constant was not significantly different from zero at 0.16%. Whatever their magnitudes, both long run output and TFP growth in UK agriculture have been abysmally low, with output stagnating and any small TFP gain due to reduced inputs[7].

Table 1: Comparison of the decomposition and modelling approaches to output and TFP growth

	WORLD		UNITED KINGDOM	
	Factor cost output trend growth rate contributions[8] %	**Signif. growth eqn coeffct.**	**Factor cost output trend growth rate contributions %**	**Signif. growth eqn coeffct.**
		1981-2015		
Labour	0.18	No	-0.19	No
Land	0.09	No	-0.09	No
Livestock Capital	0.09	No	-0.04	0.3979 **
Machinery Capital	0.14	No	-0.22	No
Materials inputs	0.36	0.851 ***	0.06	0.8020 ***
All Factors	0.86		-0.48	
Output	2.20		-0.06	
TFP / Constant	1.22	0.012 ***	0.42	0.0016 No

IV. Ten-year period changes in world and country output and TFP growth

Figs A.3.2 show changes in world factor cost shares, factor trend growth rates, output input and TFP growth rates for periods 1981-1990, 1991-2000, 2001-2010, and 2010 -2015. It reveals the increasing cost shares of labour and land over the period more latterly for crop inputs (fertilizer) though offset by a lower cost share for livestock inputs. Labour and materials together accounted for over 55% of input costs Machinery and livestock capital cost shares remained relatively constant post 1990. Factor trend growth rates remained sub 2.5%pa, with strong decline in labour over the whole period, a strengthening of land growth rates (though still less than 0.7%pa), a sharp increase in machinery capital growth rates, and a decline from their high of 2%pa in crop inputs between 2002-10, and 2011-15. Global agricultural output rose from over 2.2% to 2.6% by 2010, but dropped back to 2.0% by 2015. The overall reduction in input growth rates over the period however, resulted in global agricultural TFP rising from 0.7% in the period 1981-1990 to 1.9% in the post millennium decade. However, the average

[7] It is interesting to note that the Defra TFP series shows an annual trend average growth rate for output of 0.15% and 0.84% for TFP over the same period (author's estimates). Again, barely different from zero, and indicating a lower input growth rate than the modelling or decomposition of the USDA series in Table 1. https://www.gov.uk/government/statistics/total-factor-productivity-of-the-agricultural-industry

[8] As the dataset only supplies 10-year factor cost shares, mean shares for the period 1981-2915 were calculated as the geometric mean.

annual growth in TFP fell to 1.4% between 2011-2015, signifying perhaps the lower levels of general economic growth post 2007-8 financial crisis[9].

Fig A.3.3 illustrates the changes in world output growth rates decomposed into its factor cost, and TFP rate components[10]. The shrinking contribution of labour and land are evident and with the exception of the period 1991 -2000 the relative constant contributions from machinery capital and material inputs. The growth rate in total inputs as a whole contributed 1.2% to output growth in 1981-1990, falling to 0.6% 1991-2000, before rising to 0.8% in 2001-2010. For the latter 5 years it fell again to around 0.6%. To some extent 2001-2010 seems unusual. The total input growth contributions in1991-2000 we not dissimilar, nor were the associated output growth and hence TFP rates. If anything, it was probably the increased growth in material inputs during 2001-10 that generated the higher growth rates of output and TFP.

Figs A.3.4 present the individual country 10-year decompositions of factor contributions to output growth. Comment here is restricted to the UK. Fig A.3.5 compares the growth rates for outputs, inputs and TFP derived from the USDA and Defra data sources. Whilst there are some differences, it is interesting to note that the general patterns are similar, although the USDA decomposition has a lower output growth rate for the latter period, but also a lower input growth rate producing a higher TFP estimate than that of Defra. The main point here is that despite the overall long-term performance of UK agricultural output and TFP growth rates, the period 2011-15 has seen some recovery to rates which have outstripped Australia, India and Canada, and equalled those of Brazil, although still have some way to catch the USA[11].

V. Some tentative conclusions and comments

From a global perspective, output and TFP growth rates in 2011-15 were lower than in the previous 10-year period, and below the levels of 1991-2000. This clearly poses a challenge for humanity in terms of meeting future food demand, and using the range of resources in agriculture more effectively. Maintaining output growth will be essential, and it is somewhat misleading to interpret a rise in the TFP growth rate through lower input growth rates when output growth remains low or even negative. Given that variable input materials (feeds and fertilizers) have been the primary engines of driving output growth rates, it begs the question of whether there is a measurable contribution to output growth from some of the fixed factors, or are we measuring it correctly. A simple ratio of total output to a specific input as partial productivity is also misleading given the contributions from other factors which may also be embedded in output growth. From a modelling perspective, the growth rates of capital

[9] The variance of annual growth rates have also followed a cyclical pattern around a rising trend post 2001, reaching its highest levels 2011-15. Might this be indicative of less stable market conditions globally and more severe weather events?

[10] Note the reversed scale with the lowest values at the top of the vertical axis. This is necessary given an idiosyncrasy of Excel, which does not cumulate correctly the values in a stacked bar graph when there are negative values in the column. This results in the maximum level of the column being below the output growth level as it only cumulates the positive values whilst displaying the negative value below the zero axis. Reversing the axis scale is the only solution! The graphs for individual countries shown in Fig A.3.4 are similarly shown with reversed vertical axis scales.

[11] Albeit that the latest Defra data to 2018 indicates that output growth rates 2011-2018 have fallen relative to 2011-15, but input growth rates were lower too, but not sufficiently to reduce the average TFP growth rate over the longer period.

land and labour rarely featured as significant drivers of output growth, but then, their impact is somewhat longer term relative to the annual impact of material inputs. Clearly improvement in the quality of these inputs will enable the direct material inputs to be more effective too, but as the latter have the greatest immediate effect on output and TFP growth, it should certainly focus some attention on their intrinsic quality enhancement as part of the agri-technology and productivity drives, as more targeted applications of crop inputs, for example must have practical limits.

From a UK perspective, the results from the long-term analysis if we believe that TFP growth is an important determinant of sector competitiveness are not encouraging. With an agriculture sector policy framework for post-Brexit which on the one hand is to encourages productivity growth, and on the other attempts to de-intensify production through the new environmental land management programme in which building natural capital will feature prominently, it is likely to present contradictory signals and incentives for farmers. Much of the UK output growth has already been achieved by reduction in the growth of inputs, especially fertilizers and to a lesser extent animal feeds. It seems unlikely that aggregate output growth will respond rapidly to policies relating to natural capital enhancement which by their very nature will require years to come to fruition, nor if environmental externalities are to feature as negative outputs, then interpreting the meaning of TFP will become that more complex to understand, less meaningful as a simple output-input ratio, and perhaps less relevant as an indicator of sectoral performance.

APPENDIX 1: MEASURING TFP AND ITS GROWTH DECOMPOSTITION

Measuring Total Factor Productivity growth.

Following Fuglie (2015) we define TFP as the ratio of aggregate output *Y* to aggregate input *X*

Hence $TFP = \frac{Y}{X}$ which can be expressed as

$$\ln(TFP) = \ln(Y) - \ln(X) \quad (1)$$

The (annual) rate of change/growth rate in TFP is thus:

$$\frac{d}{dt} ln(TFP) = \frac{d}{dt} ln(Y) - \frac{d}{dt} ln(TFP) \quad (2a)$$

which states that the percentage rate of change in TFP is the difference between the growth rate in output and input.

The growth rate in output Y, is

$$\frac{d}{dt} ln(Y) = \frac{d}{dt} ln(X) + \frac{d}{dt} ln(TFP) \quad (2b)$$

viz. the sum of the growth rates in inputs and total factor productivity.

We can write $\frac{d}{dt} ln(Y)$ as $\ln(\frac{Y_t}{Y_{t-1}})$ *or* $ln(Y_t) - ln(Y_{t-1})$

Given that total output and total input of agriculture are multi product -multi input elements, we can write (2a) as

$$\ln(\frac{TFP_t}{TFP_{t-1}}) = \sum_{i=1}^{n} R_i \ \ln(\frac{Y_{it}}{Y_{it-1}}) - \sum_{j=1}^{m} S_j \ln(\frac{X_{jt}}{X_{jt-1}}) \quad (3)$$

where R_i are the revenue shares of the Y_i outputs making up Y and the S_j are cost shares of the j inputs X_j making up X in (1)[12]. For each factor, X_j , $\sum_{j=1}^{m} S_j = 1)$

[12] Fuglie (2015) ibid adds the caveats that this assumes a constant returns to scale underlying technology such as a Cobb Douglas production function (e.g. Y=kX1a X2b where a+b=1), , profit maximisation which ensures output elasticity wrt to an input equals the cost share of that input, and markets are in long run equilibrium.

If we represent growth rates by $g(\cdot)$ so that $g\ (Y) = \frac{d}{dt}ln(Y)$ etc, then Eqn (3) can be written as

$$g(Y) = g(TFP) + \sum_{j=1}^{m} S_j\ g(X_j) \quad (4)$$

With estimates of factor cost shares, factor and output growth rates we can derive the growth rate of TFP, and hence the relative contributions of TFP and factor growth to changes in aggregate agricultural output.

Fuglie *op ci*) takes this further in deriving the cost-share based contribution of an individual input X_1

$$g(Y) = X_1 + g(TFP) + \sum_{j=2}^{m} S_j\ g(X_j/X_1)\ . \quad (5)$$

This is not pursued in this paper but could also readily be adopted by a small change to the specification of Eqn (6) viz. Eqn (7)

Output models

Given the difficulties of obtaining complete factor cost share data across many countries, , an alternative approach to explaining output growth using the same data set has been explored, by modelling and direct estimation of output growth .

The approach was as follows:

We specify a more general growth rate functional form, though following (4) as:

$$g(Y) = \alpha + \sum_{j=1}^{m} \sigma_j\ g(X_j) + \tau T + \varepsilon \quad (6)$$

And the partial productivity of factor X_1 as

$$g(Y) = \alpha + \sigma_1 g(X_1) + \sum_{j=2}^{m} \sigma_j\ g(X_{j/}X_1) + \tau T \quad (7)$$

Where T is time denoting a time trend, and ε the residual. α, σ_j and τ are estimated parameters.

The coefficient α can be interpreted as a non-direct input related constant element in the output growth equation modified by τ each year in the event of there being a significant trend in the output growth series[13]. In effect it can be considered to approximate to the growth rate of TFP from the basic identity of the decomposition Eqn (4). However, the σ_j are not input cost shares as in Eqn (4), because they are not constrained to sum to unity, nor may they indeed possess statistically significant coefficient estimates. Rather, they are estimates of the marginal contributions of the growth rate of each input to output growth, as opposed to the proportion of output growth that each cost share $S_{j\ in}$ equation (4) accounts for. They therefore represent a resource-based estimate of output growth and TFP.

The model coefficients in Appendix 2 were estimated using ***gretl***[14] econometric software. All estimated equations presented have no colinear independent variables, no residual serial correlation and residuals are stationary I(0).

APPENDIX 2: DETAILED ESTIMATION RESULTS FOR OUTPUT: WORLD AND SELECTED COUNTRIES

A.2.1 WORLD

Model 1: OLS, using observations 1981-2000 (T = 20)

Dependent variable: WLD_OP

	Coefficient	Std. Error	t-ratio	p-value	*signif*[15]
const	0.0112164	0.00231649	4.842	0.0001	***
WLD_material	0.847267	0.131205	6.458	<0.0001	***

Mean dependent var	0.021790	S.D. dependent var	0.012990
Sum squared resid	0.000967	S.E. of regression	0.007328
R-squared	0.698494	Adjusted R-squared	0.681743
F(1, 18)	41.70022	P-value(F)	4.48e-06
Log-likelihood	70.99553	Akaike criterion	−137.9911
Schwarz criterion	−135.9996	Hannan-Quinn	−137.6023
rho	0.173717	Durbin-Watson	1.516933

Model 2: OLS, using observations 2001-2015 (T = 15)

[13] We can also consider that the growth form of Eqn (5) is a special case of an ARMAX model $(1\text{-}\Phi B)Ln(Y_t) = \alpha + \Sigma_j \sigma_j\ (1\text{-}\ \beta_{jt}B)ln(\ X_{jt}) + \theta(B)\varepsilon_t$ where Φ and $\beta_{jt}=1\ \forall j$.

[14] Gnu Regression Econometrics and Time-series Library. Open source software http://gretl.sourceforge.net/

[15] *** , **, and * indicate coefficients are statistically significant from zero at the 1% (P≤0.01), 5% P≤0.05), or 10% P≤0.1).

Dependent variable: WLD_OP

	Coefficient	Std. Error	t-ratio	p-value	
const	**0.0316685**	**0.00887991**	**3.566**	**0.0044**	***
WLD_material	**0.640121**	**0.0849830**	**7.532**	**<0.0001**	***
WLD_labour	**−0.919189**	**0.265567**	**−3.461**	**0.0053**	***
time	**−0.000735545**	**0.000309481**	**−2.377**	**0.0367**	**

Mean dependent var	0.023297	S.D. dependent var	0.011195
Sum squared resid	0.000183	S.E. of regression	0.004073
R-squared	0.895968	Adjusted R-squared	0.867596
F(3, 11)	31.57886	P-value(F)	0.000011
Log-likelihood	63.59099	Akaike criterion	−119.1820
Schwarz criterion	−116.3498	Hannan-Quinn	−119.2122
rho	−0.123716	Durbin-Watson	2.160481

Model 3 ARMAX, using observations 1981-2015 (T = 35)

Dependent variable: WLD_OP

Standard errors based on Hessian

	Coefficient	Std. Error	z	p-value	
const	**0.0124361**	**0.00162050**	**7.674**	**<0.0001**	***
phi_2	**−0.421689**	**0.152740**	**−2.761**	**0.0058**	***
WLD_material	**0.851602**	**0.0756886**	**11.25**	**<0.0001**	***
time	**−0.000116638**	**7.15805e-05**	**−1.629**	**0.1032**	

Mean dependent var	0.022436	S.D. dependent var	0.012102
Mean of innovations	0.000039	S.D. of innovations	0.005607
Log-likelihood	131.5707	Akaike criterion	−253.1414
Schwarz criterion	−245.3646	Hannan-Quinn	−250.4568

rho = -0.479243

A.2.2 BRAZIL

Model 1: Cochrane-Orcutt, using observations 1982-2000 (T = 19)

Dependent variable: BRA_OP

	Coefficient	Std. Error	t-ratio	p-value	
const	**0.0145800**	**0.00419574**	**3.475**	**0.0029**	***
BRA_material	**0.679752**	**0.105613**	**6.436**	**<0.0001**	***

Statistics based on the rho-differenced data:

Sum squared resid	0.006579	S.E. of regression	0.019672
R-squared	0.765302	Adjusted R-squared	0.751497
F(1, 17)	41.42566	P-value(F)	6.15e-06
rho	−0.033384	Durbin-Watson	2.030594

Model 2: ARMAX, using observations 2001-2015 (T = 15)

Dependent variable: BRA_OP

Standard errors based on Hessian

	Coefficient	Std. Error	z	p-value	
const	**0.0782152**	**0.00936419**	**8.353**	**<0.0001**	***
phi_1	**−0.611080**	**0.199941**	**−3.056**	**0.0022**	***
phi_2	**−0.568948**	**0.187103**	**−3.041**	**0.0024**	***
BRA_labour	**1.78645**	**0.418644**	**4.267**	**<0.0001**	***

Mean dependent var	0.039077	S.D. dependent var	0.028100
Mean of innovations	−0.000220	S.D. of innovations	0.018150
Log-likelihood	38.37857	Akaike criterion	−66.75713
Schwarz criterion	−63.21688	Hannan-Quinn	−66.79485

Model 3: OLS, using observations 1981-2015 (T = 35)

Dependent variable: BRA_OP

	Coefficient	Std. Error	t-ratio	p-value	
const	**0.0119985**	**0.00655213**	**1.831**	**0.0764**	*
BRA_material	**0.541021**	**0.110503**	**4.896**	**<0.0001**	***
BRA_lvstkcap	**0.451506**	**0.241046**	**1.873**	**0.0702**	*

Mean dependent var	0.035806	S.D. dependent var	0.033815
Sum squared resid	0.020525	S.E. of regression	0.025326
R-squared	0.472064	Adjusted R-squared	0.439068

F(2, 32)	14.30671	P-value(F)	0.000036
Log-likelihood	80.56249	Akaike criterion	−155.1250
Schwarz criterion	−150.4589	Hannan-Quinn	−153.5143
rho	−0.279766	Durbin-Watson	2.545718

A.2.3 CHINA

Model 1: OLS, using observations 1981-2000 (T = 20)

Dependent variable: CHI_OP

	Coefficient	Std. Error	t-ratio	p-value	
const	0.0339117	0.00431576	7.858	<0.0001	***
CHI_material	0.683968	0.111490	6.135	<0.0001	***

Mean dependent var	0.051636	S.D. dependent var	0.024535
Sum squared resid	0.003700	S.E. of regression	0.014338
R-squared	0.676467	Adjusted R-squared	0.658493
F(1, 18)	37.63575	P-value(F)	8.56e-06
Log-likelihood	57.57156	Akaike criterion	−111.1431
Schwarz criterion	−109.1517	Hannan-Quinn	−110.7544
rho	−0.030751	Durbin-Watson	1.994162

Model 2: OLS, using observations 2001-2015 (T = 15)

Dependent variable: CHI_OP

	Coefficient	Std. Error	t-ratio	p-value	
const	0.0181035	0.00346418	5.226	0.0002	***
CHI_material	0.707441	0.143122	4.943	0.0003	***

Mean dependent var	0.031759	S.D. dependent var	0.013236
Sum squared resid	0.000852	S.E. of regression	0.008095
R-squared	0.652707	Adjusted R-squared	0.625992
F(1, 13)	24.43239	P-value(F)	0.000269
Log-likelihood	52.03728	Akaike criterion	−100.0746
Schwarz criterion	−98.65846	Hannan-Quinn	−100.0896
rho	−0.245120	Durbin-Watson	2.482950

Model 3 OLS, using observations 1981-2015 (T = 35)

Dependent variable: CHI_OP

	Coefficient	Std. Error	t-ratio	p-value	
const	0.0414793	0.00460319	9.011	<0.0001	***
CHI_material	0.693596	0.0820866	8.450	<0.0001	***
time	−0.000798366	0.000194837	−4.098	0.0003	***

Mean dependent var	0.043117	S.D. dependent var	0.022542
Sum squared resid	0.004283	S.E. of regression	0.011569
R-squared	0.752084	Adjusted R-squared	0.736589
F(2, 32)	48.53800	P-value(F)	2.04e-10
Log-likelihood	107.9843	Akaike criterion	−209.9686
Schwarz criterion	−205.3025	Hannan-Quinn	−208.3578
rho	−0.111961	Durbin-Watson	2.214107

A.2.4 USA

Model 1: AR, using observations 1983-2000 (T = 18)

Dependent variable: USA_OP

	Coefficient	Std. Error	t-ratio	p-value	
const	−6.07178e-05	0.00276366	−0.02197	0.9827	
USA_material	1.02445	0.0500870	20.45	<0.0001	***
u(-2)	−0.570182	0.185085	-3.0806	0.0072	***

Statistics based on the rho-differenced data:

Sum squared resid	0.005098	S.E. of regression	0.017850
R-squared	0.951064	Adjusted R-squared	0.948005
F(1, 16)	418.3389	P-value(F)	6.77e-13
rho	0.071341	Durbin-Watson	1.460347

Model 2 AR using observations 2003-2015 (T=13)

Dependent variable: USA_OP

	Coefficient	Std. Error	t-ratio	p-value

const	***0.0109990***	***0.00189918***	***5.791***	***0.0001***	******
USA_material	***0.615920***	***0.123778***	***4.976***	***0.0004***	******
u(-2)	***−0.573845***	***0.211006***	***-2.7196***	***0.0199***	****

Statistics based on the rho-differenced data:

Sum squared resid	0.001253	S.E. of regression	0.010672
R-squared	0.835599	Adjusted R-squared	0.820654
F(1, 11)	24.76084	P-value(F)	0.000418
rho	−0.188845	Durbin-Watson	2.292399

Model 3: ARMAX, using observations 1981-2015 (T = 35)

Dependent variable: USA_OP

Standard errors based on Hessian

	Coefficient	Std. Error	z	p-value	
const	**−0.00814083**	**0.00355467**	**−2.290**	**0.0220**	**
phi_2	**−0.633999**	**0.138139**	**−4.590**	**<0.0001**	***
USA_material	**0.985491**	**0.0398047**	**24.76**	**<0.0001**	***
USA_machcap	**−0.310068**	**0.123709**	**−2.506**	**0.0122**	**
time	**0.000572834**	**0.000167569**	**3.418**	**0.0006**	***

Mean dependent var	0.013507	S.D. dependent var	0.059003
Mean of innovations	−0.000252	S.D. of innovations	0.015134
Log-likelihood	96.50141	Akaike criterion	−181.0028
Schwarz criterion	−171.6707	Hannan-Quinn	−177.7814

A.2.5 INDIA

Model 1: OLS, using observations 1981-2000 (T = 20)

Dependent variable: IND_OP

	Coefficient	Std. Error	t-ratio	p-value	
const	**0.0107536**	**0.00423549**	**2.539**	**0.0206**	**
IND_material	**0.790681**	**0.0977624**	**8.088**	**<0.0001**	***

Mean dependent var	0.031418	S.D. dependent var	0.031653
Sum squared resid	0.004108	S.E. of regression	0.015107
R-squared	0.784204	Adjusted R-squared	0.772215
F(1, 18)	65.41214	P-value(F)	2.10e-07
Log-likelihood	56.52686	Akaike criterion	−109.0537
Schwarz criterion	−107.0623	Hannan-Quinn	−108.6650
rho	−0.057282	Durbin-Watson	2.061518

Model 2: OLS, using observations 2004-2015 (T = 12)

Dependent variable: IND_OP

	Coefficient	Std. Error	t-ratio	p-value	
const	**0.0142745**	**0.00801842**	**1.780**	**0.1054**	
IND_material	**0.664080**	**0.161917**	**4.101**	**0.0021**	***

Mean dependent var	0.032841	S.D. dependent var	0.035800
Sum squared resid	0.005256	S.E. of regression	0.022927
R-squared	0.627160	Adjusted R-squared	0.589876
F(1, 10)	16.82113	P-value(F)	0.002140
Log-likelihood	29.37220	Akaike criterion	−54.74439
Schwarz criterion	−53.77458	Hannan-Quinn	−55.10345
rho	−0.332389	Durbin-Watson	2.274775

Model 3 OLS, using observations 1981-2015 (T = 35)

Dependent variable IND_OP

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	**0.0107918**	**0.00354466**	**3.045**	**0.0046**	***
IND_material	**0.771782**	**0.0701691**	**11.00**	**<0.0001**	***

Mean dependent var	0.017199	S.D. dependent var	0.071655
Sum squared resid	0.027879	S.E. of regression	0.029989
R-squared	0.840299	Adjusted R-squared	0.824844
F(3, 31)	54.37104	P-value(F)	1.88e-12
Log-likelihood	75.20364	Akaike criterion	−142.4073
Schwarz criterion	−136.1859	Hannan-Quinn	−140.2597
rho	−0.110723	Durbin-Watson	2.206352

A.2.6 UNITED KINGDOM (GBR)

Model 1: OLS, using observations 1981-2000 (T = 20)
Dependent variable: GBR_OP

	Coefficient	Std. Error	t-ratio	p-value	
const	0.000373481	0.00348734	0.1071	0.9159	
GBR_material	0.749852	0.142794	5.251	<0.0001	***

Mean dependent var	0.001967	S.D. dependent var	0.024063
Sum squared resid	0.004345	S.E. of regression	0.015537
R-squared	0.605054	Adjusted R-squared	0.583113
F(1, 18)	27.57587	P-value(F)	0.000054
Log-likelihood	55.96580	Akaike criterion	−107.9316
Schwarz criterion	−105.9401	Hannan-Quinn	−107.5428
rho	−0.058269	Durbin-Watson	2.055003

Model 2: ARMAX, using observations 2001-2015 (T = 15)
Dependent variable: GBR_OP
Standard errors based on Hessian

	Coefficient	Std. Error	z	p-value	
const	0.00846879	0.00225081	3.763	0.0002	***
phi_1	−0.996841	0.215585	−4.624	<0.0001	***
phi_2	−0.638410	0.244195	−2.614	0.0089	***
GBR_material	0.821818	0.174412	4.712	<0.0001	***
GBR_lvstkcap	0.630144	0.168091	3.749	0.0002	***

Mean dependent var	0.003003	S.D. dependent var	0.039796
Mean of innovations	−0.001158	S.D. of innovations	0.017486
Log-likelihood	38.65615	Akaike criterion	−65.31229
Schwarz criterion	−61.06399	Hannan-Quinn	−65.35755

Model 3: ARMAX, using observations 1981-2015 (T = 35)
Dependent variable: GBR_OP
Standard errors based on Hessian

	Coefficient	*Std. Error*	*z*	*p-value*	
const	0.00168621	0.00237118	0.7111	0.4770	
theta_1	−0.400841	0.156604	−2.560	0.0105	**
GBR_lvstkcap	0.397918	0.158100	2.517	0.0118	**
GBR_material	0.802007	0.184073	4.357	<0.0001	***

Mean dependent var	0.002411	S.D. dependent var	0.031241
Mean of innovations	0.000209	S.D. of innovations	0.021500
Log-likelihood	84.63984	Akaike criterion	−159.2797
Schwarz criterion	−151.5029	Hannan-Quinn	−156.5952

A.2.7 AUSTRALIA

Model 1: ARMAX, using observations 1981-2000 (T = 20)
Dependent variable: AUS_OP
Standard errors based on Hessian

	Coefficient	Std. Error	z	p-value	
const	0.00594137	0.00276503	2.149	0.0317	**
phi_1	0.601975	0.209197	2.878	0.0040	***
theta_1	−0.999999	0.155591	−6.427	<0.0001	***
AUS_material	0.697055	0.0783018	8.902	<0.0001	***

Mean dependent var	0.026596	S.D. dependent var	0.055371
Mean of innovations	−0.001579	S.D. of innovations	0.020365
Log-likelihood	48.60686	Akaike criterion	−87.21372
Schwarz criterion	−82.23506	Hannan-Quinn	−86.24183

Model 2: OLS, using observations 2001-2015 (T = 15)
Dependent variable: AUS_OP

	Coefficient	Std. Error	t-ratio	p-value	
const	0.00607531	0.00659031	0.9219	0.3748	
AUS_material	1.41625	0.126692	11.18	<0.0001	***
AUS_lvstkcap	0.787787	0.205283	3.838	0.0024	***

Mean dependent var	0.004670	S.D. dependent var	0.089521
Sum squared resid	0.006974	S.E. of regression	0.024107
R-squared	0.937843	Adjusted R-squared	0.927484
F(2, 12)	90.52978	P-value(F)	5.77e-08
Log-likelihood	36.26823	Akaike criterion	−66.53646
Schwarz criterion	−64.41231	Hannan-Quinn	−66.55909
rho	−0.168441	Durbin-Watson	2.305321

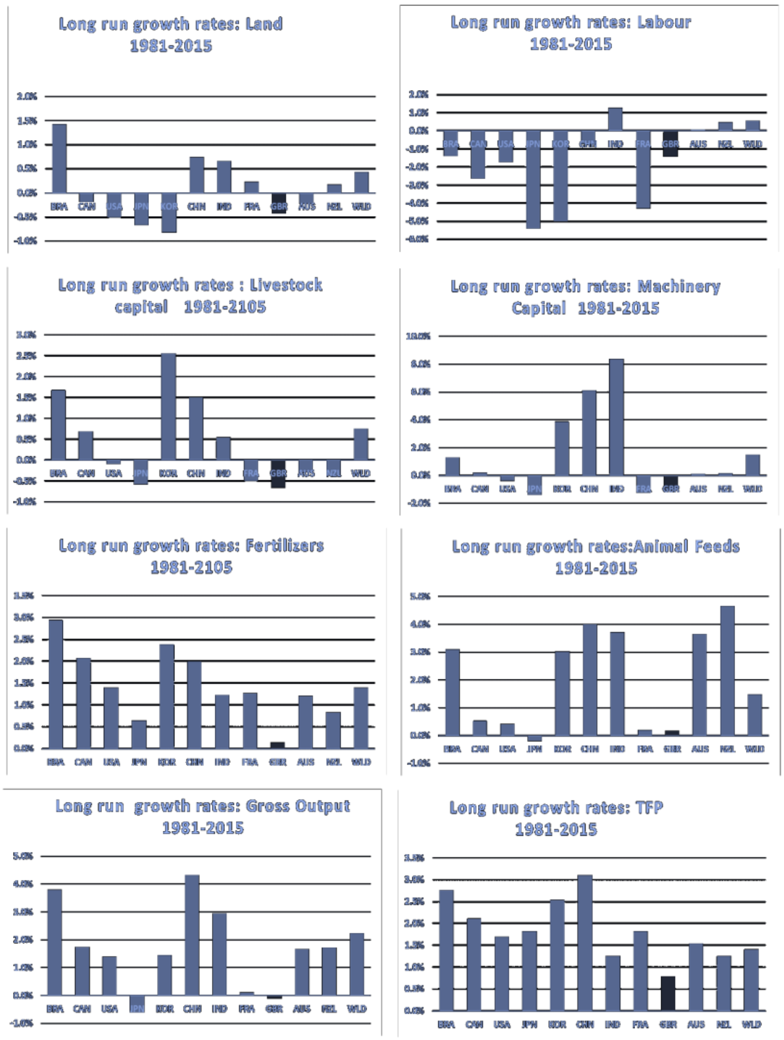
Model 3 OLS, using observations 1981-2015 (T = 35)
Dependent variable: AUS_OP

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	**0.00418808**	**0.00536437**	**0.7807**	**0.4409**	
AUS_lvstkcap	**0.800344**	**0.178076**	**4.494**	**<0.0001**	***
AUS_material	**1.01436**	**0.0805180**	**12.60**	**<0.0001**	***
AUS_labour	**−1.66464**	**0.698416**	**−2.383**	**0.0235**	**

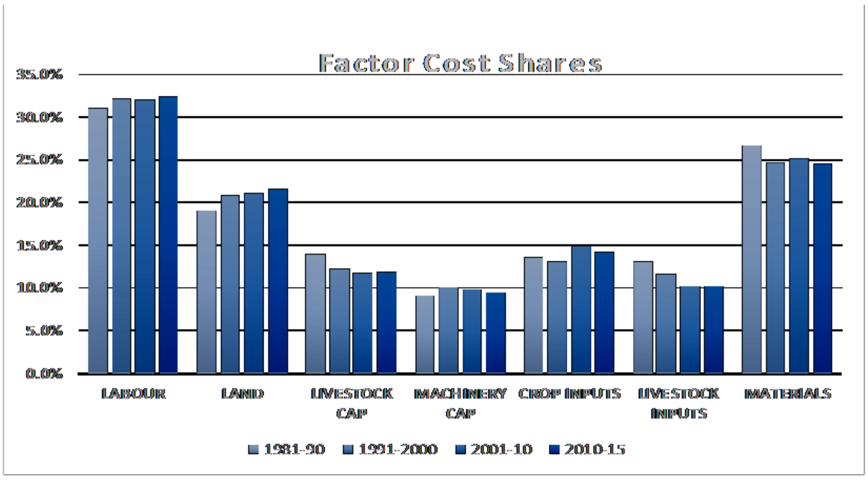
Mean dependent var	0.017199	S.D. dependent var	0.071655
Sum squared resid	0.027879	S.E. of regression	0.029989
R-squared	0.840299	Adjusted R-squared	0.824844
F(3, 31)	54.37104	P-value(F)	1.88e-12
Log-likelihood	75.20364	Akaike criterion	−142.4073
Schwarz criterion	−136.1859	Hannan-Quinn	−140.2597
rho	−0.110723	Durbin-Watson	2.206352

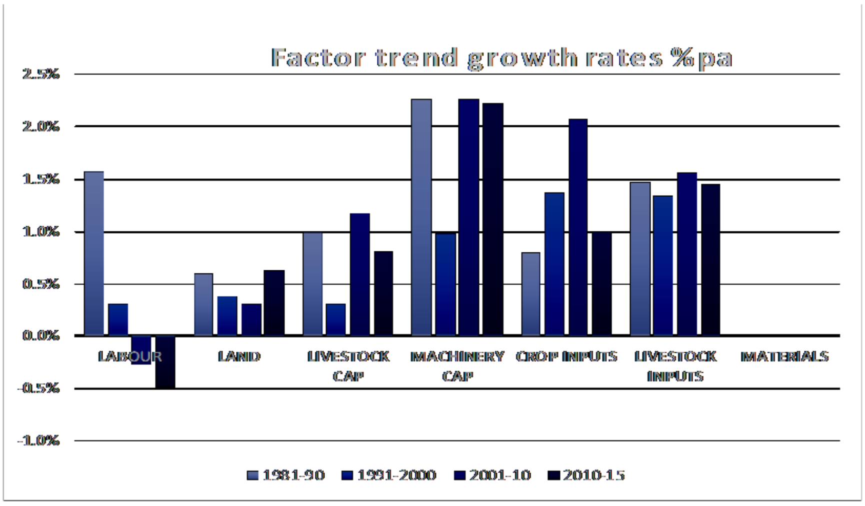
APPENDIX 3 FIGURES

Figs A.3.1 World and selected country growth rates: outputs, inputs and TFP 1981-2015



Figs A3.2 World factor cost shares, factor, output and trend growth rates by sub-periods





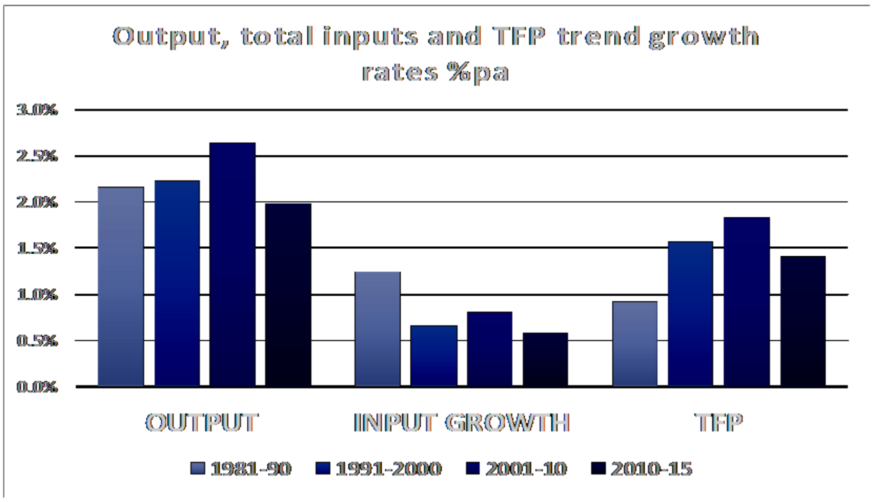


Fig A.3.3 Decomposition of world output growth by factors and TFP

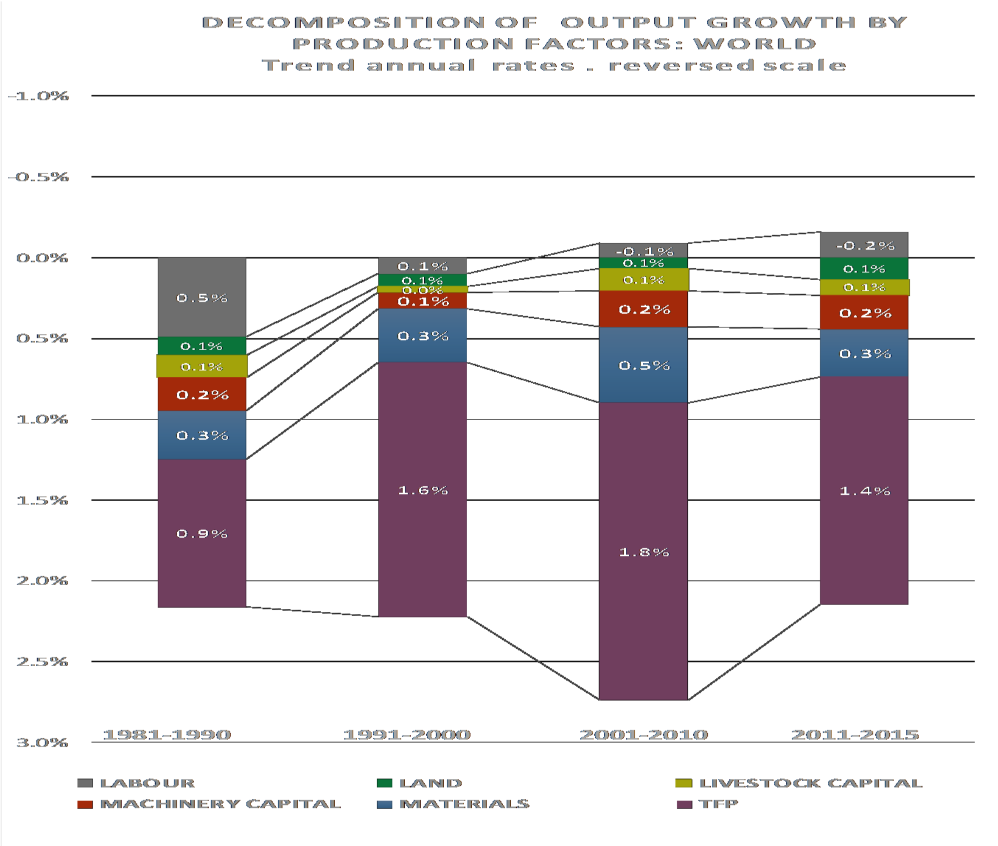
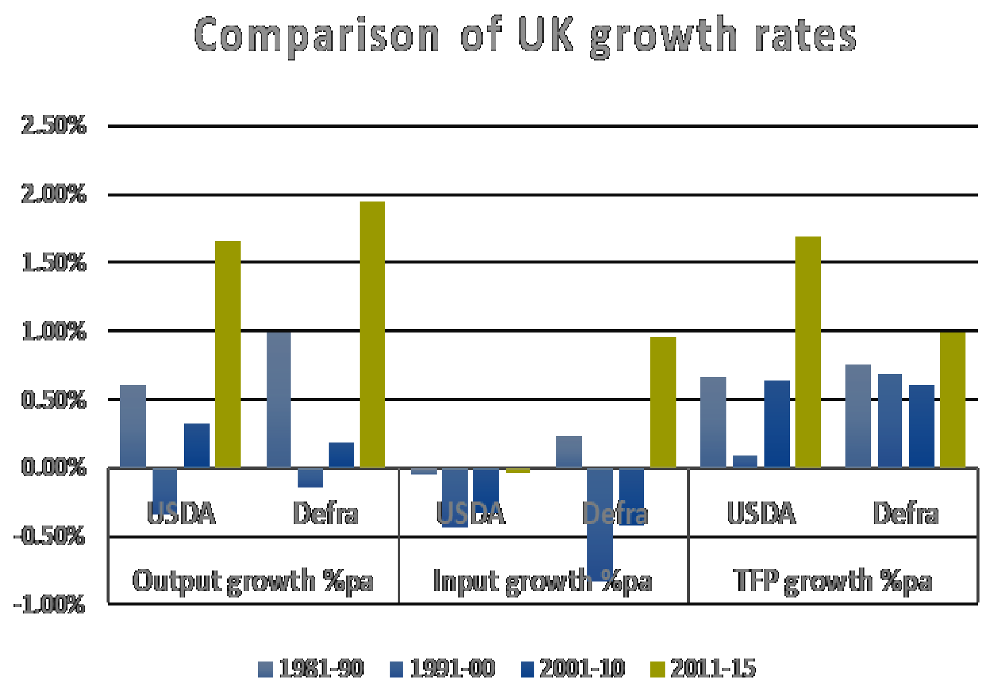
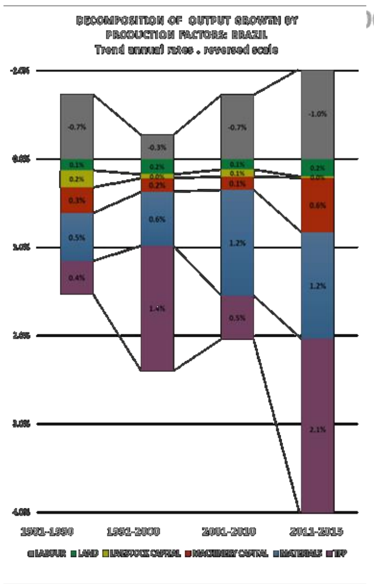


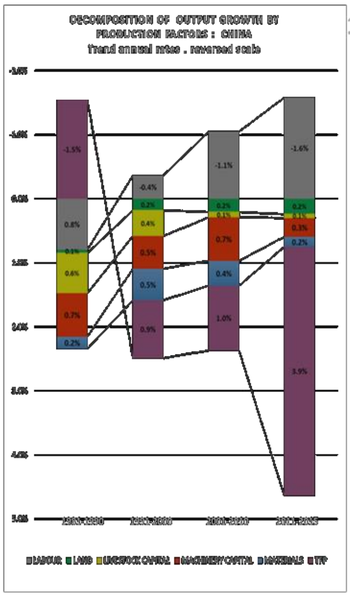
Fig A.3.5 A comparison of 10-year UK growth rates from Defra and USDA data sets



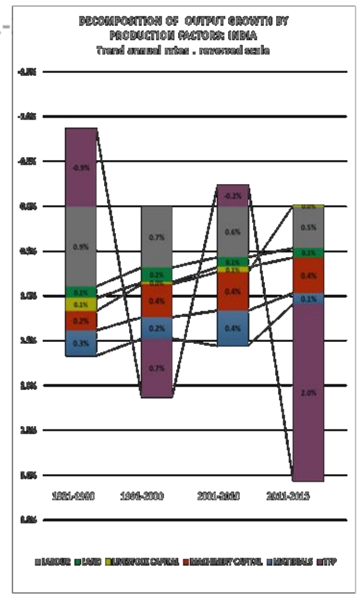
Figs A.3.4 Ten-year decomposition of TFP in selected countries



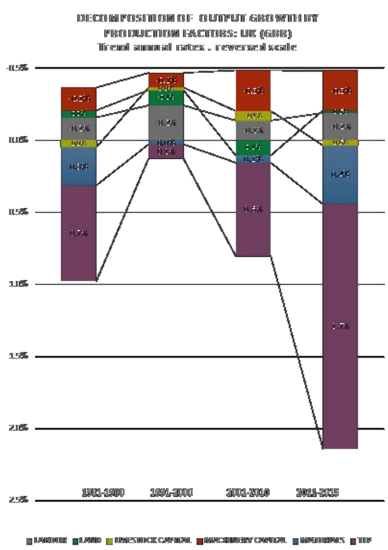
Brazil



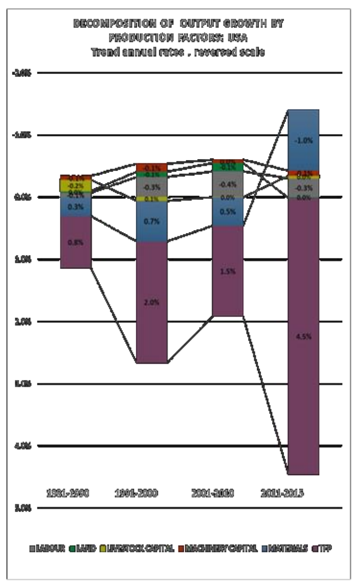
China



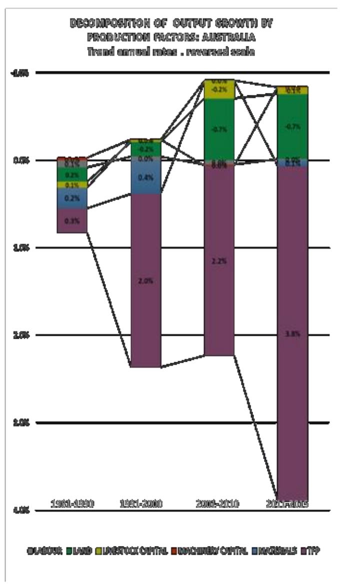
India



UK



USA



Australia

Source: author's calculations from USDA and Defra datasets

Exploring business-oriented farmers' willingness to adopt environmental practices

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Abstract

Some researchers argue that climate change can only be combated by reducing economic growth in developed countries. While this is a reasonable argument, it is very unlikely that all these countries will lower their economic activity in the short-medium run in order to favour the environment. This article explores an alternative solution that consists of affecting farmer's incentives to adopt environmental practices when they operate in a highly business-oriented paradigm. Using a structural equations approach, it was found that farmers can potentially be induced to adopt these practices by means of local policy programs.

Keywords: Climate Change; Farmer's Motivations; Business-Oriented Paradigm.

Presenters profile

Dr Daniel May is an Economist, Senior Lecturer and Researcher in Economics and Agricultural Economics at Harper Adams University. Dr May's research interest includes Farmers' Strategic Behaviour, International Trade Policy, International Trade Networks, and Agricultural Trade Liberalisation. This research has been published in different peer-reviewed journals and several articles have also been accepted to be presented in international conferences across the world. Dr May holds a PhD in Economics from University of Exeter and a PhD in Business from University of Wolverhampton.

Introduction

The parties to the 1992 UN Framework Convention on Climate Change (UNFCCC) determined to protect the climate system for present and future generations, and agreed the objective to prevent dangerous anthropogenic interference with the climate system (UNFCCC, 1992; Cicerone, 2011). The UNFCCC framework was a major achievement that should have set the world on a transformational path for human behaviour and interaction with the natural environment that would ensure future generations the opportunity for a healthy and fulfilling life.

The Intergovernmental Panel on Climate Change (IPCC) was established under the framework to produce periodic scientific assessments to enable policymakers to formulate appropriate responses and protect the climate system (Hansen, 2009). The IPCC suggested that significant problems would occur if global warming reached 2-3°C above the 1990 global temperature (Velicogna and Wahr, 2006; Schneider et al., 2007; Velicogna 2009; Hansen et al., 2011; Huber and Knutti, 2012; Francis and Vavrus, 2012). The IPCC analysis led the European Union (EU, 2008) to support policies aimed at keeping global warming to less than 2°C relative to pre-industrial times.

The EU settled for only a 50:50 chance of keeping within the 2°C target by suggesting that greenhouse gas (GHG) concentration should be stabilised below 450ppm (parts per million) of CO2equivalent (all GHG converted to global warming potential of CO2) (EU, 2008). The 2°C target was later reaffirmed by the US led agreement, the Copenhagen Accord, at the 2009 United Nations Climate Change Conference in Copenhagen (Copenhagen Accord, 2009). However, this agreement failed to include any commitment to reduce emissions to achieve the 2°C target (Anderson and Bows, 2011).

According to Anderson and Bows (2011), there is now little chance of limiting temperature increase to 2°C due to political inaction resulting from prioritisation of economic growth over global warming mitigation. They suggest that extremely dangerous climate change can only be avoided if a period of planned austerity replaces economic growth in developed countries.

The present article argues that there are alternative ways to address the climate warming problem without necessarily compromising economic growth. This is particularly relevant when realising that slowing down economic activity in developed countries is unlikely given the political pressure that this would imply for policymakers in these countries. Based on the literature on farmers' behaviour, it is argued in this article that firms can potentially be induced to adopt friendly environmental strategies even when operating within a business-oriented paradigm. This possibility is explored in the current investigation by adopting a structural equation modelling approach that was designed to identify motivational drivers of environmental strategies adoption. For this purpose, a sample of farmers in the UK was used in the study.

The Conceptual Framework

The issue of farmer's behaviour has attracted the attention of academics and policymakers over the last two decades. The aim of this approach is to gain an understanding of the drivers of a determined beneficial behaviour with the purpose of inducing this behaviour by policymakers (Senger et al. 2017). For example, this approach has been adopted to target agricultural safety and health interventions (Petrea, 2001); promote the adoption of soil conservation practices (Wauters, et al. 2010); help farmers to cooperate (May, 2012; Arancibia et al., 2017); explain production diversification (May et al., 2012; Senger et al, 2017); and identify ways to facilitate business competitiveness (May, 2015), among others.

In spite of this research, little has been done to explore the incentives of farmers to adopt environmentally friendly practices to deal with weather change when they operate in a business-oriented paradigm. This is consequently the research gap that the present article aims to fill. In considering this gap, the following research question is proposed: Can farmers who operate in a highly oriented business paradigm be induced to adopt environmental practices?

In order to answer this question, the current investigation proposes a simple business-oriented behavioural conceptual framework with the potential to inform about drivers that may be used to influence farmers' willingness to adopt environmental practices. This framework is presented in the following figure.

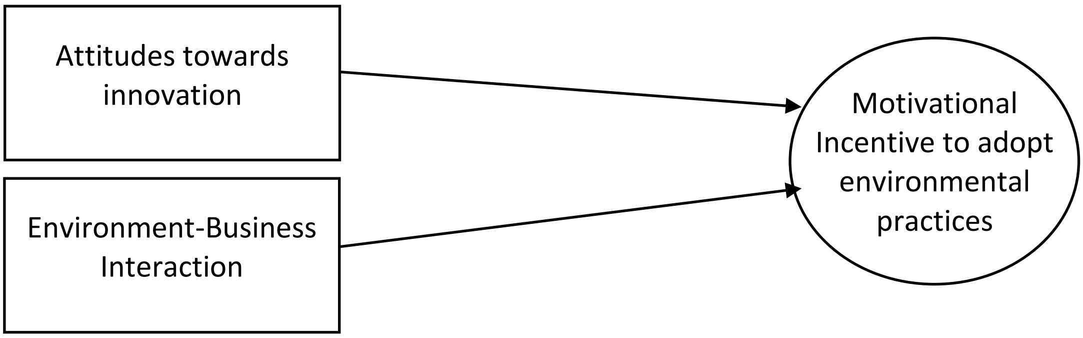

Figure 1. Business-oriented behavioural conceptual model.

According to this model, farmers' incentives to adopt a beneficial environmental practice in their business depend on their attitudes toward innovation. That is, a farmer who is risk averse will probably be less willing to innovate in these practices. In contrast, farmers who are less risk averse will probably be more inclined to adopt environmental strategies in their business. In this model, these incentives also depend on the interaction between environment and business. For example, if a farmer is not aware about the effects of climate change on his/her business, or if this individual is not aware about the damage that is causing to the environment, then he/she will probably be less interested in adopting environmental practices. These ideas are captured in the following hypotheses: H1: More innovative farmers are more willing to adopt environmental practices; and H2: Farmers who understand the interaction between environmental threats and the business are more willing to adopt environmental practices.

Methodology

The structural equation modelling methodology was adopted to test the proposed hypotheses by developing an empirical version of the conceptual model in Figure 1 by means of AMOS software. This methodology corresponds to a multivariate statistical analysis technique that combines factor analysis and multiple regression analysis with the purpose of analysing structural relationship between measured variables and latent constructs. This technique has the advantage that is able to estimates the multiple and interrelated dependence in a single analysis.

In this methodology, a number of fit indices are recommended to establish whether, overall, the model is acceptable in the sense that paths identified by the model are significant (Schumacker and Lomax, 2004). The following suggested fit indices were adopted in this investigation:

Relative chi-square (or normed chi-square): This is the chi-square for the model divided by the degrees of freedom (this rescaling allows the chi-square index to be less sensitive to sample size). In AMOS this index is called CMIN/df and tests the null hypothesis that the observed covariance matrix is similar to the predicted covariance matrix. If the CMIN/df is not significant, the model is regarded as acceptable. The criterion for acceptance varies across researchers, ranging from less than 2 (Ullman, 2001) to less than 5 (Schumacker and Lomax, 2004).

Comparative fit index (CFI): The CFI, also known as the Bentler Comparative Fit Index, compare the model of interest with a more restricted model referred to as the null model that assumes no relation among the indicators of the model (Fan et al., 1999). In this index values that approach 1 indicate acceptable fit.

Goodness of fit index (GFI) and adjusted goodness of fit index (AGFI): The goodness of fit index (GFI) is a measure of fit between the hypothesised model and the observed covariance matrix. That is, it is a measure of the relative amount of variances and covariances jointly accounted for by the model. The adjusted goodness of fit index (AGFI) corrects the GFI because the latter is affected by the number of indicators of each latent variable. Formally, the AGFI uses mean squares instead of total sums of squares. The GFI and AGFI range between 0 and 1, with a value of over .9 generally indicating acceptable model fit. (Marsh et al., 1988; Baumgartner and Hombur, 1996)

Root mean square residual (RMR): This index is defined as the square root of the average or mean of the covariance residuals of the observed and predicted covariance matrix. Values less than 0.9 are considered acceptable (with zero representing a perfect fit), but the maximum is unlimited (Marsh et al., 1988; Browne and Cudeck, 1993; Hu and Bentler, 1995).

Root Mean Square Error of Approximation (RMSEA): This is a test based on non-centrality used to assess a model's fit. It consists of examining the point estimate and comparing it with a certain fixed cutoff value, say c (Kelley and Lai, 2011). In this context, if the point estimate is smaller than c, the model is considered to have a certain degree of fit (e.g. close fit, mediocre fit, etc.). A value of RMSEA below 0.05 indicates close fit and values up to 0.08 are considered reasonable (Browne and Cudeck, 1993).

PCLOSE: This is an index that tests the null hypothesis that RMSEA is no greater than 0.05. If PCLOSE is less than 0.05, the null hypothesis is rejected, and conclude that the computed RMSEA is greater than 0.05, indicating lack of a close fit (Wan et al., 2012).

In order to obtain the latent variables of the model, a questionnaire was carried out with 364 farmers in the UK. The sample strategy consisted of a mix of stratified and snowball techniques. That is, key regions of the country were targeted and in each of them a seed farmer was used to identify additional potential participants in their regions. The questionnaire contained a set of statements and the farmers were asked to indicate their view about these statements using a five-Likert scale (i.e. strongly disagree; disagree; indifferent; agree; and strongly agree). The data was collected in year 2014. A factorial analysis was carried out to identify the statements that were used in the constructs of the conceptual model.

Results

The structural model that resulted from the collected data is presented in Figure 2. The variables/statements in this model are described in Table 1. Finally, the indicators used to validate the model are presented in Table 2.

The resulting model includes four observed variables in the motivational latent construct, three observed variables in the attitude latent construct, and two observed variables in the interaction latent construct. The information presented in Table 2 shows that the values of the relevant indicators are within the required threshold levels implying that the resulting model is validated by the data.

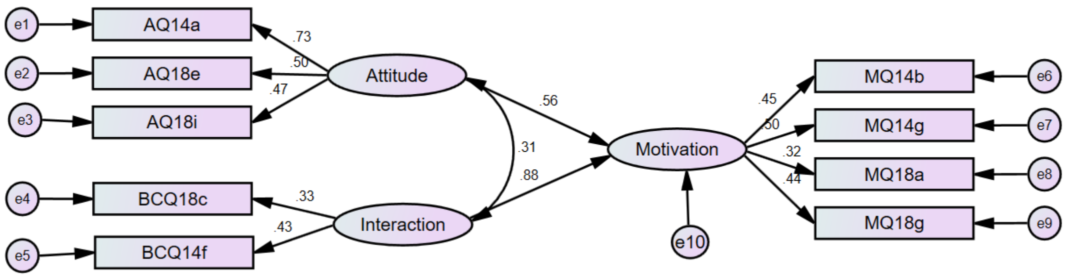

Figure 2. Structural equations model.

Table 1. Variables/statements included in the model.

Motivational Variables	Corresponding Statements
MQ14b	Farming practices will need to change to maintain food production in the future
MQ14g	I am looking for ways to improve the energy efficiency of my business
MQ18a	I would be willing to invest in adapting to weather risk if I got an adequate return on investment
MQ18g	I expect to invest in helping my business cope with weather risk
Attitudes Variables	**Corresponding Statements**
AQ14a	I like to try new things on my farm
AQ18e	I take business risks more often than other farmers
AQ18i	If necessary, I would change the way I farm to maintain farm productivity
Interaction Variables	**Corresponding Statements**
BCQ18c	I think farm profits would benefit from reducing agricultural greenhouse gas emissions
BCQ14f	In future the weather will impose additional costs on my business

Table 2. Indicators of the model.

	Threshold levels	Model
cmin/df	<3 good; <5 permissible	2.125
CFI	>.95 GREAT; >.90 TRADITIONAL; >.80 PERMISSIBLE	.919
GFI	>.95	.970
AGFI	>.80	.943
RMR	<.09 (THE SMALLER THE BEETTER)	.030
RMSEA	<.05 GOOD; .05-.10 MODERATE; >.10 BAD	.056
PCLOSE	>.05	.306

Discussion

The empirical model in Figure 2 strongly supports the conceptual framework presented in Figure 1. This suggests therefore that business-oriented farmers' motivation to adopt environmentally friendly strategies can be assessed using this framework.

According to the results, farmer's motivation to adopt environmental practices is captured by four liker-scale statement. The first one indicates that farmers who are aware of the potential scarcity of food in the future as a consequence of climate change would be willing to change their farming practices in order to maintain food production. On the other hand, it is inferred from the second statement that motivated farmers would be willing to deal with the environmental problem by improving the energy efficiency of the business. This is the statement with the highest correlation suggesting that this is a relevant concern for these farmers. In relation to the third statement, the results revealed that farmers would be motivated to adapt to weather risk as long as this change reports a reasonable return on investment. This statement, however, has a low correlation with the construct motivation implying that while return on investment is an important motivational factor, it is not the most determinant. Finally, motivated farmers would in general be willing to help the business to cope with weather risk.

The results revealed that these motivations are influenced by farmers' attitude towards investment. In particular, it was found that the statements "I like to try new things on my farm", "I take business risks more often than other farmers" and "If necessary, I would change the way I farm to maintain farm productivity" are positively correlated to farmers' motivation. Note that the first statement has the highest correlation implying that willingness to experiment in the farm is an important motivational driver. In contrast, the last statement has the lower correlation suggesting that while maintaining the level of productivity is important for farmers, it is not the most relevant motivational driver.

Finally, it was also found that farmers' motivation is influenced by the knowledge they have about the interaction between weather change and their business. This is reflected in the statements "I think farm profits would benefit from reducing agricultural greenhouse gas emissions" and "In future the weather will impose additional costs on my business". This suggests that farmers who are aware of the detrimental effects of weather change on their business are more motivated to adopt environmentally friendly strategies.

Conclusions

The aim of this research is to explore whether business-oriented farmers can be motivated to adopt environmentally friendly practices to deal with the issue of climate change. The results from the structural equations technique revealed that motivated farmers would be willing to adopt environmentally friendly strategies to improve the energy efficiency of the farm in order to protect the business against weather risk and to maintain the level of production in the future. This motivation can be reinforced if the investment on friendly environmental strategies offers the farmers a reasonable return. The results also revealed that these motivations are positively influenced by farmers' attitudes toward innovation. In particular, it was found that motivated farmers to adopt environmental practices are less risk averse, willing to explore new avenues in the farm, and interested in adopting innovations that allow them to maintain the productivity of the farm. Finally, farmers' knowledge of the effects of weather risk on their profits and production costs positively affects their incentives to adopt environmentally friendly strategies.

There are two main implications of this finding. Firstly, some researchers argue that slowing down economic activity is the only way to face the problem of weather change. While this argument is reasonable, it is very difficult to implement because this would cause political pressure on policymakers. In contrast, the results obtained in this article revealed that it is possible to address this problem by targeting farmers' motivations. Secondly, the results offer some alternatives to policymakers in terms of policies that may be introduced in order to motivate farmers to adopt energy efficiency improving strategies. One of them is to implement local programs with the potential to induce positive attitudes towards innovation and reduce the level of risk aversion. This could be done with the assistance of educational strategies accompanied with funds for innovation. The other possibility is to offer capacitation to farmers with the purpose of transferring relevant knowledge about the effects of weather change on their business.

To finish, it is important to recognise that this research only includes the farming sector. Consequently, the positive effect of inducing farmers' behaviour on the environment may not be strong enough. In considering this limitation, an obvious extension of this investigation is to investigate motivational drivers in other sectors. This extension if left for future research.

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Break-Even Analytical Techniques for New Technology Adoption Evaluation

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Abstract

A plethora of challenges arises from farm managers considering the adoption of new agricultural technologies continually being developed. While detailed economic analysis of these advancements are the most desirable technique in evaluating their potential, lack of data regarding these new investments, especially the benefits one can expect to accrue from their use, is typically faced by early adopters. To the extent that simple tools can be used to provide an estimate of target benefits that need to be realized, presumably the decision-making process for those considering adopting the technology can be assisted. This study develops and explores a number of examples of break-even analytical methods.

The break-even speed required to economically justify the adoption of high speed planting is first considered. The break-even new speed required may be derived through application of the quadratic formula:

$$s_n = \frac{-\beta_1 \pm \sqrt{\beta_1{}^2 - 4*\beta_2\beta_0}}{2\beta_2}$$

Where:

$$\beta_2 = \sum_c AR_c * \frac{HRS_c}{\varepsilon}$$

$$\beta_1 = -\left(\sum_c AR_c * \frac{HRS_c}{\varepsilon} * s_o \; - \text{RC}*\varepsilon*\frac{1}{s_o} * A + \; OC_p - \varepsilon * \frac{R\&MF_o}{s_o} * A\right)$$

$$\beta_0 = -(\text{RC}*\varepsilon * A - \varepsilon * R\&MF_n * A)$$

HRS_c = hours suitable for planting during the optimal window for crop c

AR_c = P_c*YF_c as the Additional Revenue component for crop c

YF_c = the Yield Factor for crop c which is the increased yield (bu/ac) expected from planting during the optimal window ($Y_{c,pw1} - Y_{c,pw2}$)

RC = ($WR+FP*FCR+R\&MF_t$) as the Reduced Cost component

FP = the Fuel Price ($/gal)

FCR = the Fuel Consumption Rate coefficient (gal/hr) for the tractor used

$R\&MF_t$ = the Repair and Maintenance Factor for the Tractor ($/hr)

$\varepsilon = \frac{8.25}{W*E}$ as the engineering factor exclusive of speed

A = land area planted

An example application reveals that a break-even speed of 9.87 km/hr when compared to a base conventional speed of 8 km/hr for conventional planting technology for the base conditions assumed.

Additional break-even analytical equations are developed. A break-even yield increase example for variable rate seeding rate and N application indicates that corn yields would need to increase by about 85 kg per ha to cover the cost differences for the precision technology. A break-even reduction in input application is used to consider automatic section control. The results show that a 3.90% decrease in input usage is needed from unduly applying chemicals where they are not required. Other break-even equations have been developed including width of machinery, efficiency of field machinery operation and land area in production. Further diverse examples of varying technology adoption decisions will be applied to these and other break-even tools as might facilitate discussion.

Presenters profile

Dr. Carl R. Dillon is a Professor in the Department of Agricultural Economics at the University of Kentucky. His general research interests and experiences are in production economics and farm business management. He is an expert in the application of quantitative techniques, especially mathematical programming, to agricultural economic analysis. His primary research focus has been upon evaluation of the potential of alternative production practices and new technology for profitability and risk management. Most recently, he focuses upon the area of precision agriculture.

Understanding the Drivers of Adoption of Multiple Agricultural Technologies in Nigeria

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Abstract

The important roles of agricultural technologies in bolstering productivity as well as ensuring food security and reducing poverty are well established in the literature. Despite these benefits, coupled with concerted efforts at creating awareness on adoption of these technologies in developing countries, adoption rates among farmers have been perceived to be generally low, especially in SSA. Understanding the drivers or inhibitors of adoption of agricultural technologies is therefore crucial for effective planning and implementation of technology dissemination schemes in these countries. Using a cross-sectional data collected from the 2015 Nigeria General Household survey, our study assessed the factors influencing the adoption of multiple agricultural technologies in Nigeria, while also considering the drivers of adoption intensity of these technologies at farm household level. The technologies considered include improved seeds, inorganic fertilizer, mixed and intercropping techniques, and organic fertilizer. The results from the study showed that farmers' adoption of different agricultural technologies and their intensity of use depend on the age of household head, gender, education, household size, and household's wealth status. Therefore, programme design for the dissemination of multiple agricultural technologies should consider differences in socio-economic conditions of farm households, and the adoption of the most suitable agricultural technologies for specific farm household conditions should be promoted.

Keywords: Agricultural Technology, Multivariate Probit model, Ordered Probit Model and Nigeria,

JEL Classification: C31, Q12, Q16

Presenters profile

Zainab Oyetunde-Usman is currently a Ph.D. Candidate at the Natural Resources Institute, University of Greenwich, under the sponsorship of the Commonwealth Scholarship Commission, United Kingdom. Her research evaluates the impact and drivers of agricultural technology adoption in developing countries. She holds a Masters degree in Rural Development & Agribusiness at the Szent Istvan University in Hungary, being sponsored by the Food and Agricultural Organisation (FAO), she graduated with a Distinction. Her first degree was at the renowned University of Ibadan in Nigeria where she bagged a First-Class Degree in Agricultural Economics. She has participated in several conferences, contributed to research knowledge and worked in various capacities with development organisations.

Building more resilient farm businesses with the capacity to adapt

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Abstract

Farmers in Australia work in a challenging and constantly changing environment. The increase in variability of seasonal conditions and the expectation that the climate will continue to get warmer and drier, and more variable, coupled with increased exposure to global supply and demand of commodities creates a challenging work environment. Farm managers who want to succeed will need to seize opportunities while simultaneously manage the risks, so building resilience by having the capacity to adapt to changing circumstances in a timely manner is essential for the modern-day farmer.

Success in farm performance is dependent on organisational skills and timely decisions. Farmers work in a complex environment and make many decisions varying in the level of complexity from simple to very complex. Our focus is to provide a solution for farmers who want to understand the interaction between complex variables, enabling them to make more informed decisions.

FARMSMART® is a whole-farm-business analysis tool developed in collaboration with growers, farm consultants and scientists. Designed as a desktop application, its current form is an excel spreadsheet, which can help farmers to manage risk, particularly in terms of seasonal and market volatility, as well as scenario planning for investment opportunities. The point of difference for this decision support tool is the integration of science in both the cropping and livestock systems.

FARMSMART® has the capacity to analyse a mixed cropping and sheep enterprise. It generates a five-year profit and loss statement, a five-year statement of position, and financial ratios. It calculates net present value and internal rates of return comparing scenarios for an individual farmer, using their own data. This paper is about FARMSMART®, including why and how it was developed.

Keywords: FARMSMART®, Risk management, Decision support tool

Presenters profile

Lucy Anderton is the founder and principal consultant for LA.ONE economics & consulting. Established in 2016, LA.ONE provides bespoke economic analysis for clients helping them improve productivity and performance. Based in Australia, Lucy also farms in partnership with her husband on a 3500-hectare broadacre mixed farming enterprise growing wool, prime lambs, wheat and barley. Her experience in the agriculture sector includes working for government in economics and policy, farm business management and rural financial counselling. In 2016 she graduated with a master's in science from University Western Australia. FARMSMART® is a farm business analysis tool she has developed with growers for growers.

Economic Benefits of Variable Rate Application Depending on In-field Heterogeneity

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Abstract

This study analyses the potential of precision farming – specifically, variable rate application (VRA) of seeds, fertilizer and crop protection chemicals – to increase economic returns in arable production by lowering input use and/or increasing crop yields. The cost side of implementing the respective technologies is not in scope of this study. While a number of studies exist that investigate the relative advantage of VRA compared to flat rate application under the given conditions of test farms, we wanted to better understand in particular how the potential of VRA to increase economic returns depends on the in-field variability at different locations.

To this end, case studies were conducted based on *agri benchmark* typical farms in different agro-climatic zones worldwide (USA, Canada, Sweden, Australia). These typical farms are models which reflect the prevailing production systems and economics of farms in the respective regions. Variability within actual fields at the locations of the typical farms was determined using satellite-based biomass modelling. Then two scenarios of variable rate application strategies with their respective input savings and output increases were calculated (conservative and average). They are based on literature results on the potentials of VRA and validated by local experts. Finally, the economic effect of the respective physical changes in input and output quantities relative to a typical flat-rate application was calculated using the *agri benchmark* typical farm models as basis.

Results indicate that the potential returns of VRA per hectare increase with the yield level and intensity of production at a location. In the USA (Iowa), the returns at 73 EUR/ha were more than five times as high as the 14 EUR/ha under (West) Australian conditions in the average scenario. The returns from VRA per unit of harvested output were found to depend on in-field variability: The higher in-field variability, the higher the return of variable rate application. In Australia, with the highest level of variability within plots, the economic return of variable rate application was as high as 7.73 EUR/t in the average scenario, compared to the USA with a low level of in-field variability and returns on VRA of 5.75 EUR/t. Overall, we conclude that it is important for a farm decision maker considering the implementation of VRA to determine the conditions at the farm's specific location – especially in-field heterogeneity – to be able to assess the economic potentials.

Presenters profile

Simon Walther is an agricultural economist at the Thünen Institute (Federal Research Institute for Rural Areas, Forestry and Fisheries in Braunschweig, Germany) with a focus on digital farming technologies, as well as the economics of arable production systems worldwide in the context of the agri benchmark network. Besides, he runs his own arable farm. After his dissertation on the competitiveness of different farm types in Ukrainian arable farming at Thünen Institute, Simon worked five years in Strategic Marketing (at John Deere) and Product Management (at 365FarmNet, a digital farm management platform) before re-joining Thünen Institute.

Small households' efficiency in typical steppe in Inner Mongolia

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Abstract

Livestock production has increased in Inner Mongolia, China, despite widespread documentation of grassland degradation. To begin investigating the relationship that produces these trends, we studied farm level decisions of herder households. We estimated herders' household economic efficiency in typical steppe in Inner Mongolia in 2009 and 2014 using household survey data. During this 5-year period, herders' operating cash margins decreased, but not significantly. However, their enterprise trading profit, enterprise gross margin, operating profit, net profit, and return on sheep unit all increased significantly. The correlation between stocking rate and the economic variables were all significant, except cash margin and return on sheep unit. The ANOVA analysis showed that as the stocking rate increased, the return per sheep unit increased first and then decreased, although the return per hectare grassland kept increasing.

Key words: small household, livestock productivity, typical steppe, stocking rate

Presenters profile

Dr Ping Li is an agricultural social economist at Institute of Grassland Science, Chinese Academy of Agricultural Sciences. Originally trained in grassland resources management, she has worked over 10 years in grassland science. Her current research interests include the household production, policy impacts and herders' decision making, *et al*. With a research background of both natural science and social science, Dr Ping Li is inclined to treat human-livestock-grassland as a whole community and study the interaction among them. She has worked on several multidisciplinary projects investigating the mechanism and drivers of the herders' decision-making.

Background

The sustainable use of rangelands in Eurasia has been in question for decades (Briske et al. 2015; Thwaites et al., 1998; Wang et al., 2017; Xiao et al., 1995). Over the past 60 years there have been dramatic shifts in economic conditions and consequently policy changes in rangeland and livestock management in the Inner Mongolian Autonomous Region (IMAR), China (Ho 2001, Kang et al. 2007, Wu et al. 2015).

Households make production choices based on beliefs and perceptions about the relative utility of various livelihood activities. This can include many factors, but here they focus mostly on herd production decisions like farm costs, benefits, and risks of internal and external factors of production. While grazing studies in Inner Mongolia often collect data on stocking rates and ecological parameters, few report basic information on household economic parameters. Li *et al.* (2007) collected data on livestock feed input costs from 16 households which suggested household incomes decreased over time while feed input costs increased. Many of the previous studies on livestock production in the IMAR recommend a joint management strategy between livestock systems and the ecosystem, but few studies have collected household financial data that might help justify this recommendation. Understanding the financial position of livestock producers in the changing grassland ecosystem allows us to create benchmarks to study household decisions regarding livestock productivity as it relates to ecological health and economic livelihoods.

Research area and methods

This research was done in Xilingol Prefecture, Inner Mongolia Autonomous Region, which lies in Northern China. Household surveys with structured questionnaires were used in this research. Three rounds of survey were carried out in 2010, 2015 and 2018, respectively, 120 households were selected using a stratified random method in 2010 and then return visited in 2015 and 2018. The data collected in 2010, 2015 and 2018 were used for analysing stocking rate change. The data collected in 2010 and 2015 was used for analysing the production efficiency and its relationship with stocking rate.

Stocking rate in this research is defined as the grazing density, which means the animal numbers that are raised on one unit of grassland, the unit was sheep unit/hectare. Other animals were transferred to sheep units according to Li *et al.* (2018).

Farm level production efficiency was estimated using the Standardized Herder Household Economic Analysis Framework developed by ACIAR. The economic variables used are as follows:

Operating Cash Margin = Enterprise Income - Enterprise costs - Fixed Costs - New Machinery & tools purchases - Livestock Purchases (1)

Enterprise Trading Profit = Enterprise Income - Livestock purchases + Value of external transfers + Value of inventory change (2)

Enterprise Gross Margin = Enterprise Trading Profit - Enterprise Costs (3)

Operating Profit = TGM - Fixed Costs - Labour Opportunity Costs (4)

Net Profit = OP - Finance Costs (5)

Return on Equity = Net Profit / (Average Equity) (6)

The multiple linear regression was conducted in R statistics to investigate the relationship between household net profit and the herder's decisions regarding production and the household characteristics. At the beginning, the independent variables included value transferred to enterprises (e.g. hay produced from owned grassland that is fed to livestock), value of home consumed livestock, off farm income, subsidies, animal health cost, payment for new breeding, supplement payments, payments for hired labour, payment for rented land, payment for fuel and diesel, payment for water, payment for electricity, machinery maintenance fee, depreciation in infrastructure and machinery, loan interest costs, opportunity costs, household living cost including food and medicine, education etc. Household characteristics includes the number of family members, age of the householder, distance from the road, distance from city, animal number at the beginning of the year, and contracted grassland. After the collinearity is check by variance inflation factor (vif), sheep unit at the beginning of the year, opportunity cost for land, value of self-consumed livestock were dropped. Then a stepwise regression was conducted to select the variables that are significantly correlated with net profit.

Results

Productivity changes

The household productivity variables have changed significantly from 2009 to 2014, except operating cash margin (Table 1). During the 5-year period, herders increased their livestock number and consequently the stocking rate. As a result, the enterprise income and costs both increased, however only the change in costs was significant.

Table 1: The changes of household level economics in the typical steppe

Variable	2009	2014	Significance
Enterprise Income	162819.7	178510.4	n
Enterprise Costs	47966.17	87605.61	**
Operating Cash Margin	101939	90113.14	n
Enterprise Trading Profit	173588.8	262430.5	**
Enterprise Gross Margin	125622.6	174824.9	*
Operating Profit	73689.37	165874.9	**
Net Profit	73689.37	157928.4	**
Return on Equity	21.89691	219.0595	**

*Note: *, ** mean the difference was significant at 0.05 and 0.01 level respectively, n means the difference between two years was not significant.*

Stocking rate changes over the last 8 years

In general, the stocking rate in the surveyed area increased significantly since 2009. The average stocking rates in 2018 (1.391 su/ha) increased significantly from that in 2014 (1.07 su/ha), which has increased significantly ($P<0.05$) from 2010 (0.913 su/ha). As the surveys in 2015 and 2018 were a return survey, we were able to revisit 71 households in three years. The stocking rate changes of these households are shown in Figure 1. From Figure 1 we can see that 64.7% of the respondents increased their stocking rate compared with 2010, and 39.4% increased their stocking rates continuously. Only 8.5% of the respondents have decreased their stocking rates continuously since 2010.

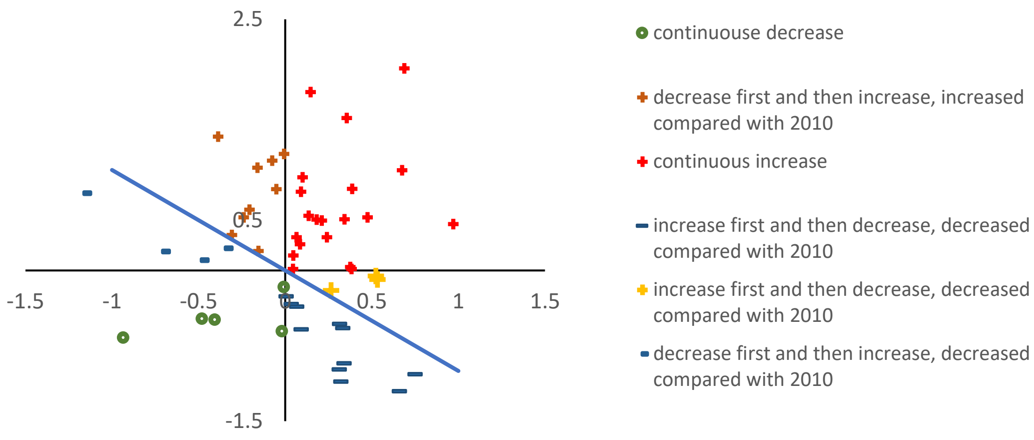

Figure 1: Stocking rate changes from 2010 to 2018

Stocking rates corelated with productiveness

Productiveness is influenced by many factors like hay production, contracted grassland area, labour number, etc. Usually, the rational producer seeks higher productiveness through enlarge production scale and adoption of new technologies. As stocking rate is one of the main decisions made in herders' production planning, if it is rational to keep a high stocking rate, then the productiveness under higher stocking rate should be higher than that under lower stocking rate.

In 2015, the official stocking rate was 0.65 su/ha, the observations ranged from 0.1 to 3.6, we clustered the stocking rate into five groups (Figure 2), and then conducted a one-way ANOVA. The result showed that the difference in productivity between groups was all significant at 0.01 level, which means stocking rate significantly influences household productivity. The relevance relationship was also estimated using two years of data, and the result showed that stocking rate was correlated with the economic variables significantly at 0.1 level, except the operating cash margin and return on equity.

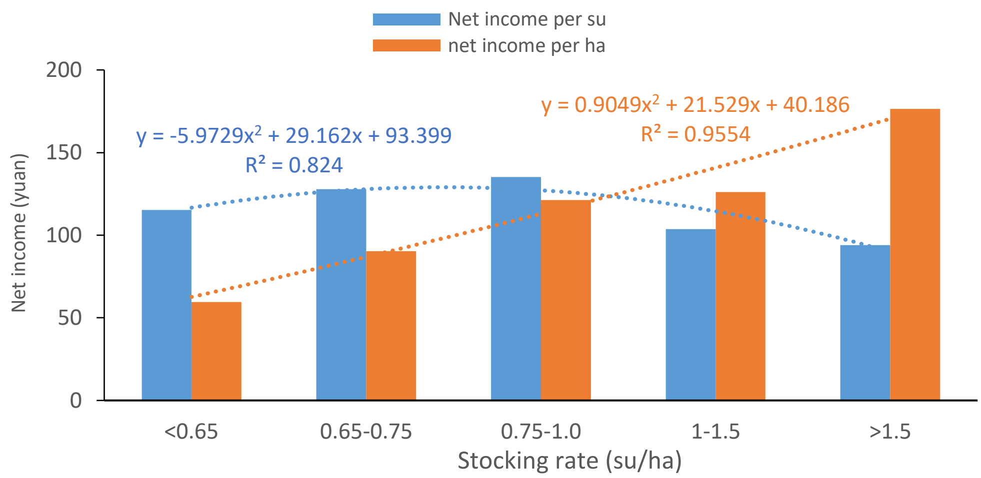

Figure 2: The influence of stocking rate on herder's productivity

It is interesting to find that the influences of stocking rate on productiveness are different when using different variables. The net income per sheep unit increased and then decreased as the stocking rate increased, however, the net income per hectare of grassland kept increasing. That answers why at the farm level, that profits have a significant positive relationship with stocking rate, while the return per sheep unit hasn't.

Drivers of household net profit

We used two models to identify the drivers of household net profit. In the first model, we only include household characteristics and decision making in production inputs and reproduction. In the second model, we include the economic feed backs from the livestock production, being the cash sales (Table 2).

Table 2: The drivers of household net profit in 2014

Coefficients:	Estimate	Std. Error	Pr(>|t|)		Coefficients:	Estimate	Std. Error	Pr(>|t|)	
Intercept	-35560	39020	0.3643		Intercept	26130	37010	0.4818	
Distance from city (m)	-775.3	334	0.0222	*	Distance from city (m)	-628.7	224.1	0.0060	**
Contracted grassland (ha)	206.3	43.43	0.0000	***	Contracted grassland (ha)	100.7	30.82	0.0015	**
Rent in grassland(ha)	141.5	43.33	0.0015	**	Payment for supplements (RMB)	-0.5589	0.2357	0.0195	*
Payment in animal health (RMB)	9.848	5.445	0.0734	.	Depreciation (RMB)	1.009	0.6545	0.1263	
Payment for Fuel &Diesel (RMB)	2.517	0.765 8	0.0014	**	Food (RMB)	1.226	0.5258	0.0217	*
Maintenance fee (RMB)	5.832	3.713	0.1193		Loan interest cost (RMB)	-3.352	0.9709	0.0008	***
Depreciation (RMB)	1.689	1.006	0.0962	.	Hired labour payment (RMB)	-1.259	0.3149	0.0001	***
Food (RMB)	1.112	0.788 7	0.1615		Opportunity cost labour (RMB)	3.86	2.203	0.0828	.
Loan interest cost (RMB)	-5.297	1.44	0.0004	***	Cash sales (RMB)	0.9983	0.0713 1	< 2e-16	***
Hired labour payment (RMB)	-1.573	0.527 7	0.0036	**	Stocking rate (RMB)	16710	6302	0.0092	**
Stocking rate (su/ha)	25050	9619	0.0105	*	Reproduction rate (%)	9580	4849	0.0508	.
Reproduction rate (%)	-15080	7147	0.0373	*	Selling rate (%)	-344400	59020	0.0000	***
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				
Multiple R-squared: 0.6241, Adjusted R-squared: 0.5807					Multiple R-squared: 0.8285, Adjusted R-squared: 0.8087				
F-statistic: 14.39 on 12 and 104 DF, p-value: < 2.2e-16					F-statistic: 41.85 on 12 and 104 DF, p-value: < 2.2e-16				

As expected, the area of contracted grassland is positively related with household net profit, and distance from the city has a significant negative effect on the net profit. Household investments in production differentiated into two parts according to their influences on net profit. Investment in rent land, animal health, fuel & diesel, and depreciation are positively and significantly correlated with the net profit, while machinery maintenance is also positively correlated with the net profit but not significantly. Loan interest cost, payment for hired labour, are negatively correlated with net profit. Stocking rate is positively correlated with the household net profit at 0.05 level.

Conclusion and discussion

Herders' decision making in regards to stocking rate is more rational than expected according to the results in household budgets and its effect on household net profit. Loan and hiring labour decreased the household net profit. Investment in renting land, fuel and diesel, machinery increase the net profit on the other hand. The findings provide some indication to herders aiming at improving their profit in livestock production.

In this research we didn't include the ecosystem cost in the analysis and in the survey, and during the survey we found herders provide little input into grassland construction or protection. As overstocking has been found to be the leading cause of grassland degradation, we suspect the economical increase in household performance was the result of over use of grassland resources.

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Time-to-adopt duration analyses of agricultural technology: What's influencing farmers' adoption decisions?

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Abstract

Precision technologies have been available at the farm level for decades. Some technologies have been readily adopted while others lagged. Analysis of 451 Kansas farms provided insights regarding duration of adoption. The lag, in years, between technologies becoming commercially available and adopted were evaluated using non-parametric and semi-parametric duration analysis. Factors likely to influence time-to-adopt were estimated using a semi-parametric Cox proportional hazard model. Duration for embodied-knowledge technologies were statistically sooner than for information-intensive technologies, indicating farmers adopt automated guidance 'quicker' than yield monitors. Duration was indirectly (directly) proportional to commercialization date of embodied-knowledge (information-intensive) technology. In general, age of operator and labour have negative impacts on time-to-adopt technologies while other factors such as years of farming experience, farm size, debt-to-asset ratio, crop insurance costs per acre have positive impacts on the time-to adopt. The impact of factors such as farm size and net farm income ratio vary across embodied-knowledge technologies and information-intensive technologies. Results are useful to farmers considering adoption, retailers targeting customers, and manufacturers managing supply chains.

Keywords: survival analysis, embodied knowledge, information intensive, commercialization, hazard rate

Presenters profile

Dr. Terry Griffin is the Cropping Systems Economist at Kansas State University. His research includes 1) valuation of farm data within the farm gates and in aggregated communities, 2) farmers' technology adoption paths, and 3) spatial statistical techniques to analyze on-farm experiments. For his achievements in advancing digital agriculture, Griffin has received the 2014 Pierre C. Robert International Precision Agriculture Young Scientist Award, the 2012 Conservation Systems Precision Ag Researcher of the Year, and the 2010 PrecisionAg Award of Excellence for Researchers. He serves as Treasurer of the International Society of Precision Agriculture. In addition to presenting across North America, Terry has delivered invited presentations in Europe, Africa, and Australia.

Introduction

Utilization of agricultural technologies within the farmgate remain a persistent issue among researchers and practitioners in terms of understanding the rate at which technologies are adopted, order in which adoption occurs, factors that influence adoption decisions, and the benefits the technology provides. Many precision technologies have been available since the early 1990s, yet adoption has not approached a plateau even after nearly 40 years (Griffin and

Yeager, 2018; Griffin *et al.*, 2019). Technology has been associated with perceived profitability from farm-level utilization. The benefits of precision agriculture have been said to be 'site-specific' (Swinton and Lowenberg-DeBoer, 1998). Given that the economics of technology are a function of the specific grower's fields and their unique management ability, profitability assessments of specific technologies have been elusive.

The diffusion of technology has been segregated into simpler and more complex versions (Davies, 1979; Coombs *et al.*, 1987; Miller *et al.*, 2019). Griffin *et al.* (2004) described technology as two distinct groups, i.e. embodied-knowledge and information-intensive, and how adoption rates differed. Embodied-knowledge technologies have been more readily adopted than information-intensive technologies (Griffin *et al.*, 2004; Griffin and Yeager, 2018; Miller et al., 2019). Digital agricultural technology gave rise to "Big Data" attracting interest across multiple industries to farm data communities (Griffin *et al.*, 2016; Coble *et al.*, 2018). This study contributes to the knowledgebase by applying duration analyses (Burton et al, 2003; Dinterman and Katchova, 2018) to Kansas farms. Griffin and Yeager (2018) applied non-parametric duration analyses to time-to-adopt data for Kansas farms using the available sample size. The current analyses build upon Griffin and Yeager (2018) by applying Cox proportional hazard parametric duration methodology to updated sample size.

An indirect way that precision agriculture has been found to affect profitability is its ability to substitute information and knowledge for fertilizer, seeds and chemicals given soil and other conditions. Several researchers have examined the reduction of purchased inputs savings from an environmental stewardship perspective and leading to better sustainability of resources Bongiovanni and Lowenberg-DeBoer (2004). Schimmelpfenning and Ebel (2016) examined the distortion between adoption of precision agricultural technologies given expected lower input costs. Their findings indicated that differences in the size of operation, education of operator and type of farm played significant roles in the adoption of technology. There was also an inconsistency in the savings as variable rate technology in some instances could result in increased input usage. The first step in assessing profitability of technology is to evaluate adoption trends. The longest running survey of precision agricultural technology adoption focuses on agricultural service providers rather than within the farm gate (Erickson *et al.*, 2017). Results of agricultural retail services are consistent with farm level estimates.

The decision to adopt, i.e. technology choice, is an inherently dynamic process. This decision is based on past decisions as well as future expectations. Duration analysis is one means to examines this dynamic decision making specifically focused on time-to-adopt (Burton *et al.*, 2003). Burton *et al.* (2003) published one of first agricultural technology adoption studies using duration analysis. They reported several theoretical studies evaluating time-to-adopt of agricultural technologies. Due to the dynamic nature of the decision and potential impactors, duration analysis was a proper means to analyse time-to-adopt. D'Emden *et al.* (2006) examined no-till adoption decisions of Australian farmers. They found cost of inputs, specifically herbicides, to be important factors in adoption decisions. Possible herbicide resistance following implementation of no-till practices complicated trade-off decisions.

Fugile and Kascak (2001) examined the adoption of conservation tillage, soil nutrient testing and integrated pest management. They reported that farm size, farmer education and land quality were associated with adoption lags of up to 20 years. Dadi *et al*. (2004) examined the adoption of fertilizer and herbicides by smallholder farmers in Ethiopia. They reported that economic incentives were most important determinant of the time farmers waited to adopt. Farmers were unlikely to adopt before evidence of profitability (Griffin *et al.*, 2018). Alcon *et al*. (2011) examined drip irrigation technology adoption in Spain. The authors found that educational factors, technological trials, availability of credit, price and information networks were among the most important factors influencing adoption timing.

As a first step into understanding farmers' perceived benefits of precision agriculture, the time-to-adopt was evaluated given individual farm operator characteristics. The overall objective of this study was to determine if time-to-adopt as well as factors that influence adoption decisions after technology commercialization was similar between individual technologies and across groups of technology.

Data

The Kansas Farm Management Association (KFMA) database includes farm-level agronomic and financial data since 1973. In 2015, KFMA economists began collecting and annually updating technology records (Griffin *et al.*, 2017). By July 2019, 656 farms reported having either 'used' or 'never used' at least one of six technologies. Of the 656 farms, 551 (84%) adopted at least one of six technologies. Technologies included global navigation satellite system (GNSS) enabled yield monitors (GNSSYM), variable rate fertilizer (VRF), precision soil sampling (PSS), lightbar (LB), automated guidance (AGS), and automated section control (ASC).

Duration is the length of time after being able to adopt that adoption occurs. Lags are measured in years between the farm adopting technology and when the farm could adopt the technology. Individual farms could adopt technology after the farm began operating and the technology became commercially available (Figure 1).

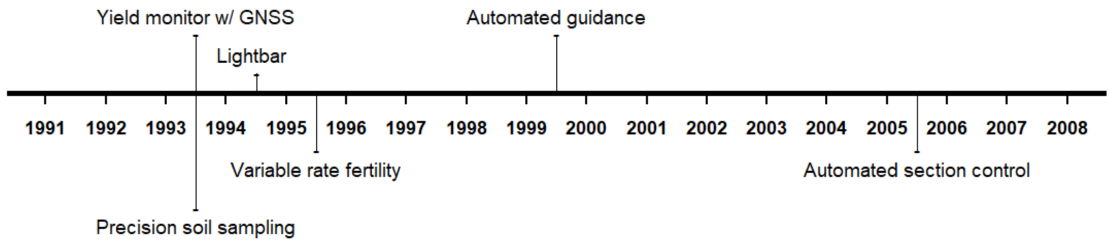

Figure 1. Date technology became commercially available

The KFMA Operator Database provides the year farm operations began and contains 824 unique sole-proprietor farms including birth year, year began farming and number of dependents. An inner join between the 824 KFMA Operator Database farms and the 656 farms with technology yielded 336 farms common to both datasets. Duration was measured for each technology, *j*, on 336 farms, *k* (Eq. 1). Farms may have different start dates because some operations began after technology became available.

$$duration = t_{jk} - \max(t_{CA_j}, t_{BF_k}) \quad (1)$$

where *duration* is time-to-adopt in years, t_{jk} is date farm *k* adopts technology *j*, t_{CA_j} date technology *j* became commercially available, and t_{BF_k} the date farm *k* began farming.

Negative duration indicated farms reported adopting technology before becoming commercially available. Some farms may have obtained access before technology became widely available; in those cases, the farms likely sought out technologies beyond their geographic region, potentially as beta users direct with the manufacturer. Alternative explanations include recall bias of either the farmer- respondent or the researcher. Continued research is being conducted regarding local commercialization dates of precision technology.

The dependent variable, duration, were graphically presented as violin plots (Figure 2). Only farms adopting at least one agricultural technology were included (n=551). Violin plots are a type of box plot that represent the relative size of the metric with areas scaled proportionally to number of observations. The x-axis scale is relative to when technologies were able to be adopted, with 0 as the base. The width of the violin plot represents proportion of farmers adopting specific technology during given duration. The purple dot represents median duration. The left side of the violin plot indicates when farmers first adopted the technology and the right side represents the most recent adoption of the technology. Vertical dotted lines represent the 25th and 75th percentile duration.

Relatively newer technologies such as automated section control (ASC) that have only been on the market for a few years, have shorter violins (as measured from left to right). Other technologies introduced to the marketplace earlier and that remained on the farm longer have extended violin shapes. Precision soil sampling (PSS) and lightbar (LB) have longer violin shapes than other technologies. Technologies with wider violin plots, e.g. ASC and AGS, were adopted by relatively large proportion of adopters during respective lag duration.

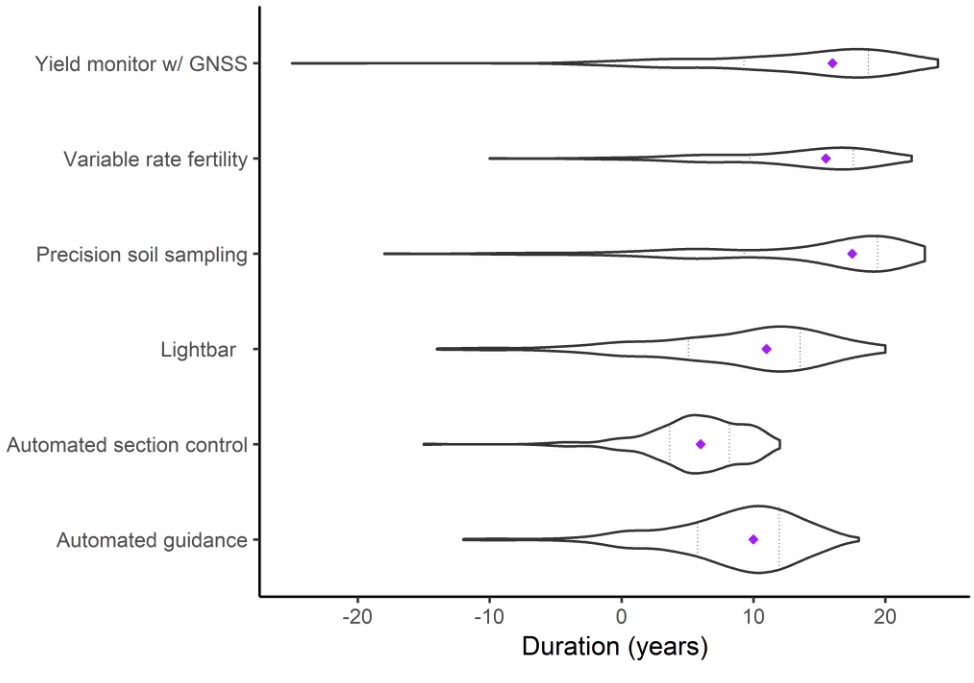

Figure 2. Duration of technology adoption

Methods

Duration analysis is concerned with time-to-event data (Greene, 2017). The timing when subjects transition from one state of the world to another is of interest. (Burton *et al.*, 2003; An and Butler, 2012). In this study, the time-to-event is when farms adopt technology. The specific question addressed by this study asks what is the chance farms will adopt after time *t*, and what factors influence adoption decisions, given that the farm has not adopted some technology by time *t*,?"(An and Butler, 2012).

Each farm was tracked over time until January 2019 or adoption. Some farms may cease operations, discontinue KFMA membership, or never adopt technology; any of these actions would cause the farm to be considered censored. Each farm was evaluated for the duration that it remained in the sample up until the adoption event. As adoption events occur, the survival rate decreases, and farms fall out of the sample. The hazard rate is the probability of farm falling out of sample at time *t,* i.e. the probability of a farm adopting given the time period.

The dependent variable, *duration*, is assumed to have a continuous probability distribution, f(*t*) (Eq. 2). Theoretically, the dependent variable is non-negative but due to recall bias and uncertainty of exact commercialization dates, some farms reported adopting before the first date possible thereby producing negative duration in this sample.

Non-parametric and semi-parametric models were estimated. A non-parametric model was estimated to determine the general shape of the hazard (and survival) functions. The probability density function is

$$\mathrm{f(t)} = \frac{\mathrm{dF(t)}}{\mathrm{dt}}. \tag{2}$$

The probability that the duration, in years, will be less than *t* is a cumulative distribution function expressed as (Eq. 3):

$$\mathrm{F(t)} = \mathrm{Pr(T \leq t)} = \int_0^{\mathrm{t}} \mathrm{f(s)ds} \tag{3}$$

where the random variable *T* has some duration less than *t*. Eq. (2) can be rewritten as a survivor function that is the probability that duration equals or exceeds *t* (Eq. 4) (An and Butler, 2012).

$$\mathrm{S(t)} = \mathrm{Pr(T > t)} = 1 - \mathrm{F(t)}. \tag{4}$$

The hazard rate is the probability that the duration will end after time *t*, given that it has lasted until time *t* (Eq. 5).

$$\lambda(t) = \frac{f(t)}{S(t)} \tag{5}$$

The Kaplan-Meier (KM) non-parametric estimator corrects for censored data in a distribution (Borgan, 2005) and therefore has a decreasing step function with a jump at each discrete event time (Colosimo *et al.*, 2002). Statistical tests were conducted on estimated curves to determine if duration differed between technologies. Duration curves were estimated as Kaplan-Meier (Therneau and Grambsch, 2000) using the **survfit()** function from **survival** package (Therneau, 2015; 2019) to R (R Core Team, 2019). Using **survdiff**() function, log-rank tests for right censored data (Harrington and Fleming, 1982) determined if estimated duration curves differed between technologies. The p-value associated with the log-rank test chi-square statistic for the null hypothesis of no difference are provided for each pair of survival curves. Duration results can be interpreted to reveal if technologies have been adopted at faster rates than others.

The Cox proportional hazard model was estimated using the **coxph()** function from **survival** package to investigate factors influencing the duration of adoption. Following Cox (1972), the Cox proportional hazard model is specified as (Eq. 6);

$$h(t) = h_0(t)\exp(b_i X_i) \quad (6)$$

where $h(t)$ is the expected hazard at time t, $h_0(t)$ is the baseline hazard and represents the hazard when all predictors X_i are equal to zero. The predictors X_i are specific farm characteristics that may influence the time-to-adopt decision. The predicted hazard (i.e., $h(t)$), or the rate of the event of interest occurring in the next instant, is the product of the baseline hazard ($h_0(t)$) and the exponential function of the linear combination of predictors. Thus, the predictors have a multiplicative or proportional effect on the predicted hazard. Finally, b_i is a vector of parameters characterizing the predictors. Given individual farm characteristics and the availability of a specific technology at time t, farmers would make adoption decisions, i.e. to adopt or not to adopt, available technology at time t or in subsequent years. A farmer will adopt the technology if expected profits from adoption V_1 are greater than the expected profit from non-adoption V_0.

Literature on adoption of agricultural technology provides myriad factors that can influence farmers' adoption of technology choices. These factors can be farmer-specific and site-specific, regional-dependent, economic, attitudinal, or market related. However, this study focuses on a selected number of factors that have been identified to most likely influence farmers' time-to-adopt decisions. Characteristics considered in this study include; the operator's age ("age"), years of farming experience ("experience"), farm size ("acreage"), net farm income per acre ("NFI"), number of workers ("labour"), per acre crop insurance expenditure ("insurance"), and debt-to-asset ratio ("D/A").

The operator's age (age) is expected to have a negative correlation with time-to-adopt. That is, older operators are expected to adopt precision agricultural technologies slower compared to their younger counterparts. Several studies (Torrez *et al.*, 2016; Dadi et al., 2004) have shown that younger farmers are more likely to adopt some form of agricultural technology.

Years of farming experience (experience) is used as a proxy for the farmer's knowledge about farming, which is likely to influence farm management decisions, including the adoption of technology. Ntshangase *et al.* (2018) show that more farming experience increases the probability of farmers adopting agricultural technology. However, other studies such as Ainembabazi and Mugisha (2014) show an inverted-U relationship between adoption and farming experience.

Farm size (acreage) represents the number of crop acres planted, which gives an indication of the size of operation. Although subtle differences in the relationship between farm size and adoption of specific types of technology, farm size generally has a positive correlation with the rate of technology adoption (Griffin *et al.*, 2016; Torrez *et al.*, 2016).

Net farm income per acre (NFI) gives an indication of the value from farming. A farmer is more likely to adopt a technology adoption perceived to lead to higher farm incomes (Mwangi and Kariuki, 2015). The lag of NFI is used in analysis to account for possible endogeneity.

Number of workers (labour) is used as a proxy for labor. Dadi *et al*. (2004) and Ahsanuzzaman (2015) show that no significant relationship exists between technology adoption and labor. However, in this study, number of workers is considered as non-operator workers only; as an indication of paid laborers who do not make management decisions.

Crop insurance expenditures per acre (insurance) is used as a proxy for risk aversion. The notion being that higher per acre costs of crop insurance indicate that farmers have higher risk aversion (Adhikari *et al.*, 2009). The effect of risk aversion on technology adoption varies across technology types; a negative relationship between information-intensive technology and a positive relationship between automated-guidance technology (Torrez *et al.*, 2016). However, in general, risk averse farmers are known to adopt technology more slowly compared to risk neutral counterparts (Sassenrath *et al.*, 2008).

Debt-to-asset ratio (D/A) gives indication of the financial standing of farms and provides information about the ability of the farmer to purchase agricultural technology. The notion being that farms with higher debt-to-asset ratios have lower financial standing and thus are less likely to invest in agricultural technology. The lag of D/A is used in analysis to account for possible endogeneity.

Descriptive statistics of variables used in the analysis are presented in Table 1. Out of a total number of 451 farms over 17-year period, the mean age of operators is 60.8 years which gives an indication that operators are older than ages reported by USDA. On average, farmers have 38.2 years of farming experience. The mean farm size is 1597.4 acres, with a standard deviation of 1149.1 acres. Average net farm income per acre is $83 per acre with a minimum and maximum value of -$1,625 and $4,446 per acre, respectively. The mean number of workers excluding operators is 0.6, with a standard deviation of 1.1 and a maximum value of 16.7 workers. The average cost of crop insurance is $8.70 per acre on average, with a minimum and maximum value of $0 and $73.90, respectively. The mean debt-to-asset ratio is 0.3, with standard deviation of 0.2.

Table 1: Descriptive statistics of variables

Variable	Mean	Std Dev.	Min.	Max.
age	60.8	11.1	27.0	95.0
experience	38.2	11.4	10.0	84.0
acreage	1597.4	1149.1	0.0	10168.6
NFI	83.2	168.0	-1624.6	4445.8
labour	0.6	1.1	0.0	16.7
insurance	8.7	6.7	0.0	73.9
D/A	0.3	0.2	0.0	1.0

Sample size: 451 farms

Results

Duration curves for the six agricultural technologies and the two main categories were compared. When duration curves are to the left of another curve, then time-to-adopt reached adoption sooner. Note that duration curves originate from survival probability equal to 1.0 on the y-axis. If curves do not diverge, then adoption paths were not statistically significantly different.

All three embodied-knowledge technologies (AGS, LB, ASC) were compared as a collective group to all three information-intensive technologies (GNSSYM, PSS, VRF). Duration curves were statistically significantly (p-value < 0.0001) different from each other with embodied-knowledge technologies adopted sooner after commercialization than information-intensive counterparts (Figure 2). Roughly one-third of farms remain likely to adopt embodied-knowledge technology (per the end of the curve where it plateaus). Almost half of farms remain as potentially adopting information intensive technology.

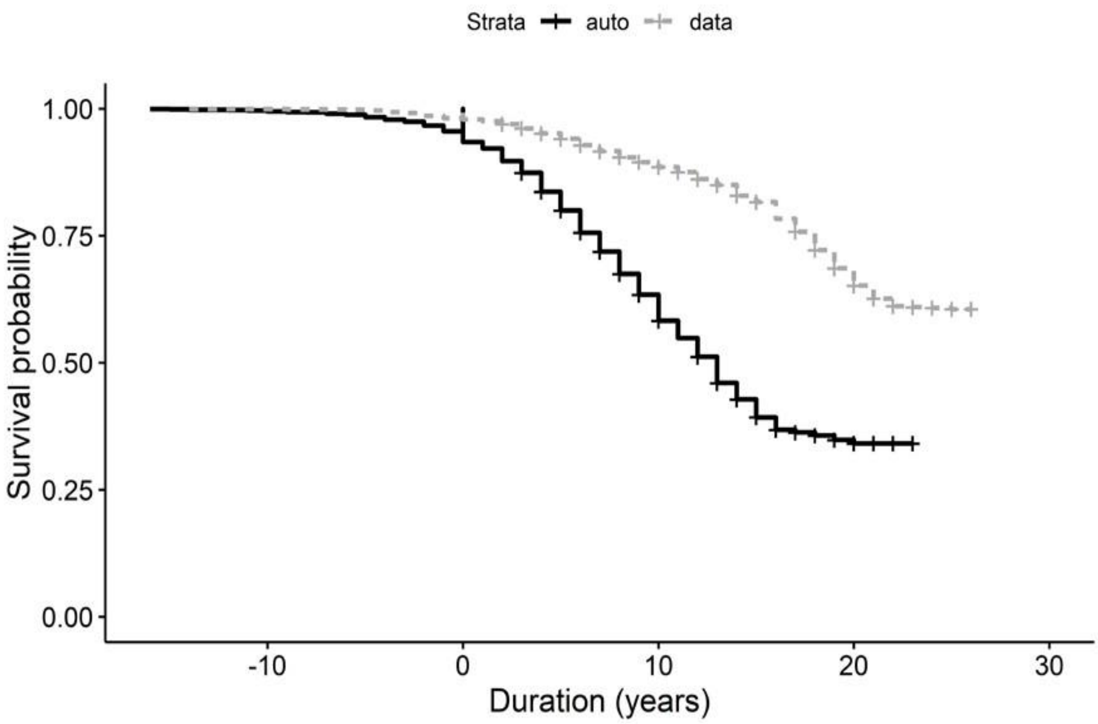

Figure 3. Duration of embodied-knowledge (auto) and information-intensive (data) technology

In addition to comparing groups of technology, duration curves were estimated for individual technologies. Duration curves for the three embodied-knowledge technologies were compared against each other. Results indicated that curves were statistically different (p-value < 0.0001) with automated section control (ASC) being adopted relatively sooner than automated guidance (AGS) or lightbar (LB) (Figure 3). Automated guidance was adopted in a relatively shorter amount of time than lightbar guidance. Automated section control is a relatively newer technology, i.e. with a more recent commercialization date; and has approximately half of farmers remaining as nonadopters. Lightbar has been commercially available longer than AGS or ASC; and has 40% of farms not adopting the technology.

Automated guidance has the least number of farms at risk for adoption at nearly one-third. Duration was indirectly proportional to commercialization dates for the three embodied-knowledge technologies.

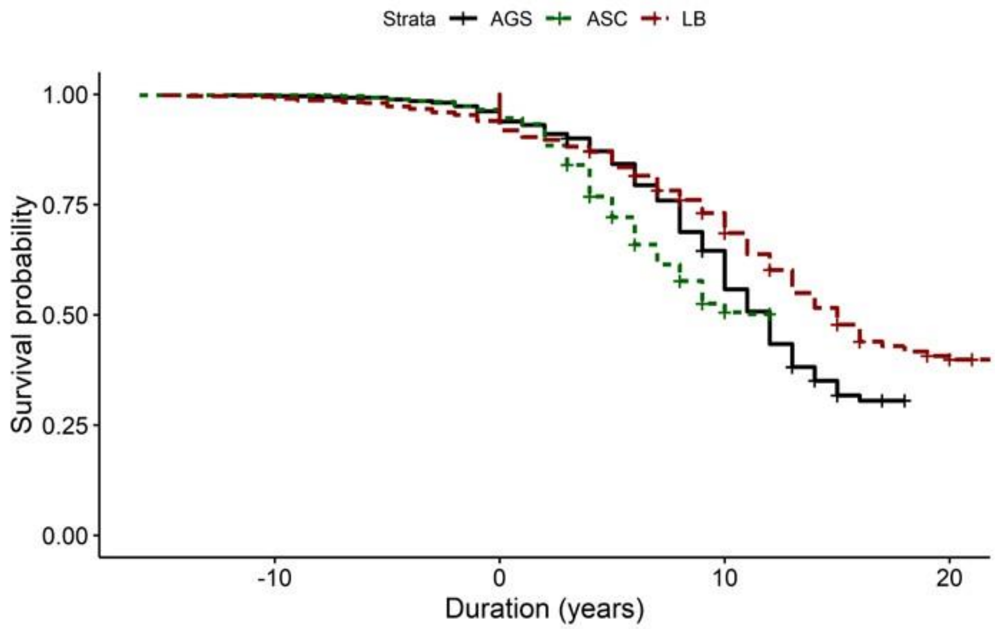

Figure 4. Duration of automated guidance (AGS), automated section control (ASC) and lightbar (LB)

Table 2. Pairwise p-values of log-rank chi-square statistic

	AGS	ASC	LB	GNSSYM	PSS
AGS					
ASC	**0.88**				
LB	<0.0001	<0.0001			
GNSSYM	<0.0001	<0.0001	<0.0001		
PSS	<0.0001	<0.0001	<0.0001	**0.79**	
VRF	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**

Duration curves for the information-intensive technologies were evaluated. Results indicated that curves were statistically different (p-value < 0.0001) with GNSS-enabled yield monitor (GNSSYM) being adopted before precision soil sampling (PSS) or variable rate fertility (VRF) (Figure 4). Unlike embodied-knowledge technologies, duration of information-intensive technology adoption was directly proportional to commercialization dates. More than half of farms are considered potential adopters of any of the three information-intensive technologies.

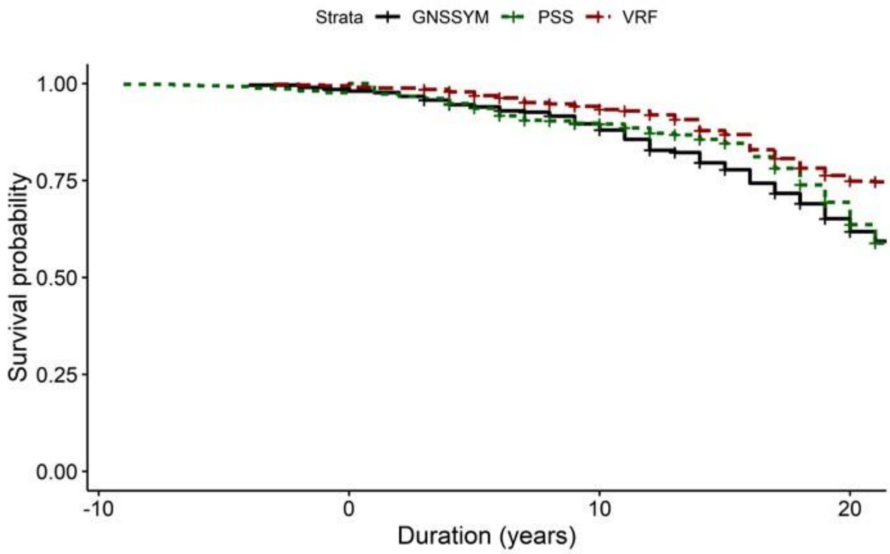

Figure 5. Duration of GNSS-enabled yield monitor (GNSSYM), precision soil sampling (PSS) and variable rate fertility (VRF)

Cox proportional hazard model results are reported in Table 3. Generally, a positive (negative) sign suggests that the conditional probability of adoption increases (decreases) with a given variable. A hazard ratio greater (less) than one denotes that the variable has a positive (negative) impact on the likelihood of adoption. A unity hazard ratio implies no impact of the a given variable on adoption.

Table 3: Time-to-adopt results for at least one technology

Variable	Coefficient	Standard Error	Hazard Ratio
age	-0.0295***	0.0008	0.9710
experience	0.0123***	0.0007	1.0124
acreage	0.0001***	0.0000	1.0001
NFI	0.0001***	0.0000	1.0001
labour	-0.0174***	0.0050	0.9827
insurance	0.0128***	0.0005	1.0129
D/A	0.1044***	0.0159	1.1101

**** p < 0.001.*
Sample size: 451 farms

The coefficient of operator's age (-0.0295) indicates that an increase in age by one year, holding all other variables constant, decreases the conditional probability of precision agriculture technology adoption by about 2.95% (97.10% hazard of adoption). This indicates that younger operators are more likely to adopt technology than older operators. Though very minimal (0.01%), an increase in farm size increases the conditional probability of adoption. This is consistent with knowledge that as farm size increases farmers are more likely to adopt technology (and more quickly). An increase in the number of years of farming experience increases the conditional probability of adoption by 1.23%. An increase in net farm income per acre, crop insurance per acre, and debt-to-asset ratio increases the conditional probability of adoption by 0.01%, 1.28% and 10.44% respectively. As labour (excluding operators) increases the conditional probability of adoption decreases by 1.74%. This means that, as the number of workers increases, there is a delay in the time-to-adopt precision agriculture technology.

Results for the factors influencing the time-to-adopt of at least one embodied-knowledge technology, and at least one information-intensive technology are reported in Table 4 and Table 5, respectively. Since earlier results show that the duration curves of embodied-knowledge and information-intensive technologies substantially differ, being able to identify which factors influence their respective time-to-adopt would be valuable.

Table 4: Time-to-adopt results for at least one embodied-knowledge technology

Variable	Coefficient	Standard Error	Hazard Ratio
age	-0.0257***	0.0009	0.9747
experience	0.0021*	0.0009	1.0021
acreage	0.0003***	0.0000	1.0003
NFI	0.0000***	0.0000	1.0001
labor	0.0018	0.0059	1.0018
insurance	0.0199***	0.0005	1.0201
D/A	0.0314	0.0195	1.0319

** p <0.1, *** p < 0.001*
Sample size: 451 farms

Table 5: Time-to-adopt results for at least one information-intensive technology

Variable	Coefficient	Standard Error	Hazard Ratio
age	-0.0392***	0.0014	0.9616
experience	0.0287***	0.0013	1.0291
acreage	0.0000*	0.0000	1.0000
NFI	0.0004***	0.0000	1.0004
labor	0.0687***	0.0082	1.0711
insurance	0.0116***	0.0008	1.0116
D/A	0.3490***	0.0272	1.4177

** p < 0.1, *** p < 0.001*
Sample size: 451 farms

In general, the signs of all the predictors are consistent between both types of technologies (embodied-knowledge and information-intensive technologies); however, coefficients differed in terms of magnitude and significance. The coefficient of operator’s age indicates that an increase in age by one year, holding all other variables constant, decreases the conditional probability of precision agriculture technology adoption by about 2.57% for embodied-knowledge technologies and 3.92% for information-intensive technologies. Farm size has no economically significant impact on time-to-adopt for information-intensive technologies, although minimal effect (0.03%) was both statistical and economical significant impacts on time-to-adopt for embodied-knowledge technologies. Net farm income per acre has no economic significant impact on time-to-adopt for embodied-knowledge technologies; however, had both statistically and economically significant (0.04%) impacts on time-to-adopt information-intensive technologies. Also, labor and debt-to-asset ratio have no statistically significant impact on time-to-adopt for embodied-knowledge technologies; however, have both statistically and economically significant impacts; 6.87% and 34.90% respectively on time-to-adopt for information-intensive technologies.

Discussion and Conclusions

Duration curves of embodied-knowledge and information-intensive technologies were expected to substantially differ with the former being adopted sooner than the latter after commercialization. Results confirmed duration statistically differed across these two broad categories. It was expected that automated guidance and section control were adopted at much higher rates than yield monitors due to differences in human capital costs to make use of data for farm management decision making. These are consistent with nearly all previous agriculture technology adoption studies.

Duration curves of similar technologies grouped within either embodied-knowledge or information intensive were not expected to substantially differ. It was somewhat unexpected that duration statistically differed among technologies within these two broad categories. Specifically, automated section control was adopted sooner than automated guidance, and automated guidance was adopted sooner than lightbar. Results may partially be explained by commodity prices and farm policies being favourable to expansion or shifts towards utilization of automated section control. Retailer marketing may also have played a role. For information-intensive technologies, GNSS-enabled yield monitors were adopted sooner than precision soil sampling or variable rate fertility. This may be due to ease of use or the perceived benefit GNSS-enabled yield monitors provide. Yield monitor adoption may also have been due to acquiring combine harvesters already equipped with the technology.

These results may be used to evaluate whether lightbar will continue to be considered an embodied-knowledge technology since the technology provides operators with visual aid to manually steer the equipment without automating the process. Arguments could be made that even though substantial technology was embodied into the lightbar, it was analogous to information-intensive given that nearly the same amount of human capital from the user is necessary to make use of the technology albeit actions are reactive rather than proactive.

In general, age of operator and labour have negative impacts on time-to-adopt technologies while other factors such as years of farming experience, farm size, debt-to-asset ratio, crop insurance costs per acre have positive impacts on the time-to adopt. Factors that influenced the time-to-adopt embodied-knowledge technologies are somewhat different from those that influence the time-to-adopt of information-intensive technologies. Farm size has no impact on the time-to-adopt for information-intensive technologies as opposed to significant influences on the time-to-adopt for embodied-knowledge technologies. Net farm income, labour, and debt-to-asset ratio have no impact on the time-to-adopt for embodied-knowledge technologies but have significant influence on the time-to-adopt for information-intensive technologies. More leveraged farms tended to have more technology potentially from the investment in machinery or possibly due to the fact that younger operators tend to adopt technology. Younger operators tend to have fewer financial resources than older more financially stable farms.

Duration was indirectly proportional to commercialization dates of embodied knowledge and directly proportional to dates of information-intensive technology. This was somewhat surprising and warrants further investigation. Uncertainty exists with respect to the exact dates that technologies became commercially available. Continued effort is being applied to finding historic documents that may push commercialization to earlier dates.

Automated technologies including guidance and section control were adopted sooner after becoming commercially available than more data intensive technologies such as yield monitors and grid soil sampling. In general, factors such as age of operators and labor have negative impacts on time-to-adopt technologies while other factors such as farm size and debt-to-asset ratios have positive impacts on the time-to adopt. The impact of some factors such as farm size, labor, net farm income and debt-to-asset ratio vary across embodied-knowledge technologies and information-intensive technologies.

Results are useful for Extension personnel working directly with farmers. Uncertainty and misinformation exist regarding which geographical regions are ahead or behind the technology adoption curve. Even locally, many farmers believe that their cohort is more advanced with respect to technology utilization. These results are useful to share with farmers and their advisors regarding actual adoption trends especially the length of time before technologies are typically put into service.

As newer agricultural technologies are introduced, manufacturers are attempting to move toward automated or embodied-knowledge technologies rather than information intensive. This has been apparent with the traditional information-intensive technologies such as yield data and especially analysis of that data to become more automated via streaming from equipment via telematics and automated processing via cloud computing. The next wave of digital technology is expected to have much shorter duration to adoption in part due to automation and in part due to farmers being acclimated to technology utilization.

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Agriculture, ICT and Economic Development: A Critical Analysis and Proposal for e-Agriculture Implementation in Nigeria

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Abstract

Information & Communication Technology (ICT) has played a significant role in various sectors globally. Since the advent of information technology, there has been a revolution on the several applications of ICT on several sectors of the economy. In today's world for the ease of human transactions and activities, several applications have been deployed, we have e-commerce, e-banking, e-governance, and hence the agricultural sector is not an exception having the e-Agriculture.

Agriculture can be said to be the main bone of livelihood in several developing countries. Two third of the populations do depend on the mainstay of Agriculture as a means of life sustenance. There should be a means of improving this sector in such developing countries so as to increase productivity.

To sure ascertain improvement on the condition of Agriculture in these countries using Nigeria as a case study, there is an immediate need and concern to enable technological development and advancement, accessibility to vital Agricultural information, availability to market information, government policies, Agricultural research works, Agricultural extension services Agricultural financing, access to inputs and implements etc. bringing it to the doorsteps of every farmer where the effective solution to all of these complex problems is the introduction and proper implementation of e-Agriculture. Using the help of the internet and mobile-telecom technologies, e-Agriculture has the measures to solve the problems encountered by farmers in an easy and efficient manner, if implemented solidly.

For the Agricultural and socio-economic development of the country, especially in the rural areas, Government's efforts to improve the Agricultural research, Agricultural education, Agricultural extension, Agricultural out-put and related policies should help in bringing qualitative life to the people. Information Technology do not only improves quality of life through various mechanisms, but can also help an average Nigerian farmer to get useful information relating to the production of crops, Agro processing demands, market support information, Agro-finance and management of farm and Agri-business.

Agriculture is the main backbone of the rural community and today's modern farming practices and technologies has been implemented properly in many parts of the world which need to be spread out to other parts lacking strong implementation of it; in this case, rural Nigeria can be taken as an example. The accessibility to ICT technologies and its infrastructures needs to be available in a proper manner for the immediate use of farmers; for them to utilize their best in their farming practices to have more production and stability.

This project is aimed at exploring and proposing an implementation guide on how Nigeria could enhance her e-Agriculture policies and strategies to assist the Agricultural output, the socio-economic axis, and the whole economy in turn; by examining and critically analyzing ICT usages and applications across the Agricultural angle.

The study examines Nigerian government e-Agriculture policies. It also proposes what e-Agricultural strategies the government should adopt to enhance the Agricultural output and socio-economic development. Furthermore, the study examines the history and current status of Agriculture in Nigeria and the current status of Nigerian information and communication technologies. The analysis addresses the role of information and communications as instruments of national development. In view of the economic status of Nigeria, the study calls on Nigerian government to adopt a cautious approach as it embarks on e-Agriculture policies and acquisition of information and communication technologies to promote national development. The study calls on Nigerian government to liberalize her Agricultural policies, establish Agricultural cooperatives, educate famers and offer telecommunications and other ICT tools and services 'concretely' in the rural areas so as to raise the Agricultural productivity which will also help in boosting the socio economy and add value to the Nigerian economy 'resultantly'.

Keywords: Agriculture, ICT, e-Agriculture, Rural Development, Socio- Economic Development, Economic Development.

Presenters profile

Abdulkareem Sani Lugga is currently a PhD student at Harper Adams University. Abdulkareem is a private businessman and project management consultant, having graduated from Ahmadu Bello University in the year 2006 with BSc in Mathematics and Coventry University with MSc in Information Technology. Abdulkareem served under the Nigerian youth service corps from 2007-2008 and immediately employed himself as a businessman and a consultant. Abdulkareem is a fellow member of the Nigerian Institute of Management and still operates as a self-employed person with head office in Abuja, Nigeria

Towards joined-up agri-innovation systems: moving beyond the individual farmer

David Christian Rose

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Abstract

Commentators claim that we are on the cusp of the 'fourth agricultural revolution' with smart technologies such as AI, robotics, the Internet of Things, drones, and aquaponics, set to change production systems beyond recognition. In order to achieve such a transformation, technologies will need to be implemented at scale. This paper briefly considers the progress made to date on overcoming barriers to technology adoption, including research on behavioural interventions and user-centred design. Much of this research, however, has tended to treat technology adoption as an isolated phenomenon, focusing on individual end users, rather than on necessary socio-technical transitions at a wider scale. Such transitions inevitably involve the strengthening of individual end user skills and a shift in attitudes, but they go far beyond the farm scale and demand change at an institutional level. The talk thus considers how agricultural innovation systems can be better joined-up so that technologies are relevant and user-centred, advice is freely available to end users, and policy-makers invest in the digital infrastructure needed to implement them at scale. As a cautionary note, the paper also suggests that principles of responsible innovation should underpin such a system to ensure that technology trajectories are acceptable and shaped by a diverse range of actors.

Presenters profile

Dr David Christian Rose has recently joined the School of Agriculture, Policy and Development at the University of Reading as Elizabeth Creak Charitable Trust Associate Professor of Agricultural Innovation and Extension. This role focuses particularly on maximising the impact of agricultural innovation through good knowledge exchange/extension. David is a Geographer by discipline, specialising in research at the interfaces of technology, science, policy, and practice. He is currently interested in understanding the social and ethical impacts of the fourth agricultural technology revolution, but has worked on technology adoption factors, user-centred design, and behavioural change in the context of agri-tech.

Prices transmission in the global soybean market and the effects of the US-China trade war

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Abstract

The global soybean markets have 3 main payers; in one hand we have China as the biggest importer, in the other hand we have the United States (US), Brazil and Argentina as the biggest exporters. In the context of the trade war between China and the US, this country imposed a 25% tariff on American soybean. The aim of this study is to understand the relationship between these 3 main markets as well as to identify the consequences of the new tariffs. The research used time prices series (Spot & Futures prices) of main player of the international market of soybean; US, China, Brazil, Argentina, and Europe for the period from January 2009 to March 2019. The research uses several economics and econometrics models to measure market power, market efficiency, and price transmission. The Granger Causality test shown a unidirectional causality between Chicago, China, Brazil, and Argentina soy markets, showing that prices in Chicago affect Chinese, Brazilian and Argentinian ones, being the only exception the Rosario Future market, in Argentina. China also is affected by Rotterdam, Brazil, and Argentina's markets. The Results from the Vector Error Correction Model found after a shock on prices on the US market, Brazilian and Argentinian markets tend to adjust with faster speed than China, showing a higher level of market efficiency. The threshold autoregressive model (TAR) shown that no long-run asymmetry is present within the markets, suggesting that the market is efficient and tariffs haven't affected the prices transmissions. The result points out that the US is still the main price maker and hold the strongest position in the trade war regardless of other international market players.

Presenters profile

Gustavo Barboza Martignone is an Agricultural Engineer (Ingeniero Agrónomo ,Facultad de Agronomía Universidad de la Republica, Uruguay). He also has Masters in International Agribusiness & Food Chain Management from Harper-Adams University, and is currently a PhD Student in Agricultural Economics at Harper-Adams University. He is also currently works as an Agricultural Planner & Agricultural Analyst in a local firm.

Public investment returns on food security and nutritional wellbeing in Nigeria

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Abstract

Despite the consensus reached by African leaders to allocate 10 percent of budgetary resources to the agricultural sector to drive agricultural growth and development, Nigeria with an average of 5.4 percent, falls below the average of other West African countries. As such, the country is facing challenges of food insecurity and very little evidence is available in literature regarding the returns of agricultural investment on welfare outcomes, especially for the case of Nigeria. Hence this study aims to provide greater insights on the linkages and pathways of public expenditures, food security and child wellbeing in order to provide key policy options that will contribute to sustainable development goals and world of zero hunger. We used both wave2&3 of the Living Standards Measurement Study (LSMA) and public expenditures data from the Central Bank of Nigeria (CBN). For this study, public expenditure is categorized into “agricultural-focused” expenditures; human capital expenditures and, physical expenditure. We then used random and fixed effect panel estimation models to examine the dynamics of public expenditures on the outcome variables. In our first approach, our findings revealed that investments in agricultural related activities had a positive and significant growth effect on food security, but human capital had stronger effects than physical expenditures. Child wellbeing was positively influenced by all the three categories of public expenditure, but agriculture and human capital expenditures had higher effect on the reducing stunting. Our second approach investigated the combined effect of the total expenditures on food security and child nutritional outcomes. The result showed that the combined expenditures had a positive and negative growth effects on food security and child nutritional outcomes. We therefore contend that government agencies should be sensitive and prioritize investments in sectors resulting to higher improved livelihood returns such as the human capital, agriculture and infrastructure.

Keywords: public expenditure, nutrition, food security, random and fixed effect panel models

Presenters profile

Motunrayo Oyeyemi is a research analyst at the International Food Policy Research Institute (IFPRI) with a wide range of research experience including food security, public expenditure, youth employment. Her specific research interest is in child malnutrition and well macro-economic welfare. Her academic background lies in agricultural economics and extension for which she obtained a bachelor’s degree from Federal University of Technology Akure, Nigeria. She equally has a master’s degree in Agriculture from the Nelson Mandela University, South Africa.

Productivity Growth in the Dairy Sector in Northern Ireland: Trends and drivers

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Introduction

The dairy sector is one of the most important agricultural industries in Northern Ireland (NI), considering that the sector has consistently ranked highest in its contribution to the overall NI agricultural economy. In 2018, the sector accounted for about 10 percent of the total active farms, as well as contributing the largest share (32 percent) of the total gross output of NI agriculture (DAERA 2018).

Despite the importance of this sector, it is still faced with a number of important challenges which include growing competition from outside dairy sector for factors of production due to increasing food and industrial demand driven by demographic and disposable income changes. In addition, following successive reforms of the Common Agricultural Policy (CAP) which have resulted to increased exposure of this sector to world markets, and consequently reduced the role of market management tools and the gap between world prices. There is the likelihood that the Northern Irish dairy sector will be exposed to greater international competition in the future as the UK seeks to negotiate Free Trade Deals across the globe in the post-Brexit era. These market and policy developments may influence the future competitiveness of the sector. Against this backdrop, it is important to gain a better understanding of the performance of this sector overtime, and also ascertain the competitiveness of the sector. A key indicator for the performance and competitiveness of sector is productivity which measures the efficiency by which a sector as whole converts input to produce output. The aim of this study is to gain an improved understanding of productivity trends and drivers in the Northern Irish dairy sector. The study has three main objectives:

i. Compute a measure of productivity at aggregate level for the dairy sector.

ii. Decompose aggregate productivity into different components: productivity growth within farms and resource reallocation between farms. This decomposition will enhance the policy conclusions that can be drawn as these components imply different pathways to improving productivity; i.e. on-farm innovation and resource reallocation between farms.

iii. Examine the factors influencing farm-level productivity of specialised dairy farms in NI.

Methodology

To achieve the first objective of the study, which is 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 as a Fisher output index divided by a Fisher input index. The Fisher Index is a bilateral in nature and is not transitive, therefore to ensure that the TFP measure is trans-temporal and can be compared across farms, we applied the adjusted Fisher index using the Eltetö Köves

Szulc (EKS) formula (Eltetö and Köves 1964; Szulc 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 as a ratio of total output and input of the sector.

To achieve the second objective, which is to decompose aggregate productivity into different components, we applied the Olley and Pakes (1996)'s decomposition method of sector-level productivity. The Olley and Parkes (1996)'s decomposition method is suitable for measuring long term changes in resource allocation which is more relevant for policy makers. This measurement can show the extent to which with-in farm technology progress and resource allocation across farms contribute to the sector-level TFP growth. Similar approach was adopted in Kimura and Sauer (2015)'s study to examine the dynamics of productivity growth in the Netherlands, Estonia, and England and Wales.

The third objective is to examine the factors influencing farm-level productivity of specialised dairy farms in NI, and this was achieved using a panel fixed effect regression model. Similar approach was employed by Sheng and Chancellor (2018) to examine the relationship between farm size and TFP in Australian grains industry.

The data used for the estimation are mainly obtained from the Farm Business Survey (FBS) for the period 2005 -2016. The FBS is conducted annually through the Department of Agricultural, Environment and Rural Affairs (DAERA). Data on price indices are obtained from Office of National Statistics (ONS) and the UK Department for Environment, Food and Rural Affairs (DEFRA).

Results and Discussion

The results revealed that the NI dairy farm sector has experienced a moderate productivity growth per year between 2005 and 2016. The sector-level TFP grew at 0.5 per cent a year. This growth indicates improvement in the efficiency with which inputs are used to produce milk and other dairy products. By breaking the years covered into two, the dairy farm sector experienced negative annual TFP growth of 1.8 per cent between 2005 and 2009, but the sector grew at 1.8 per cent a year between 2010 and 2016. During the entire period covered, the annual growth rate of output increased by 4.6 per cent and that of inputs increased by 4.2 per cent implying that the annual growth rate of output marginally outpaced the growth of input. This suggests that productivity growth in the NI dairy sector is largely driven by output growth, with inputs also increasing over the period.

Our estimates from the Olley and Pakes decomposition approach revealed that over the period (2005-2016), the aggregate productivity growth witnessed in the NI dairy sector has been largely driven by growth in with-in farm technological progress, while the resource allocation between farms appears to have a negative effect on productivity growth. Specifically, the results showed that sector-level TFP growth was detracted by 0.1 per cent a year as a result of resource allocation, suggesting that some resources have been misallocated between farms. This may be because some market factors have inhibited resources to move from less productive farms to more productive farms during the period covered.

Finally, the econometric analysis using the fixed panel approach shows that the farm-level TFP are 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 farm size, milk yield, stocking density, capital to labour ratio and shared of hired labour, while factors such as purchased feed per cow, labour input per cow, share of direct payments in farm output are negative and significantly affect TFP level of dairy farms in NI.

Conclusion

Productivity growth is an essential element in sustaining international competitiveness of the Northern Irish dairy farm sector. In light of the evolving challenges facing this sector, including increasing pressure on- and limitations to- the factors of production, climate change and rising cost of inputs, growing competition from outside agriculture for the same production factors, long term growth of the sector largely depends on continues gains in productivity.

The study concludes that the NI dairy sector experienced a moderate productivity growth in terms of efficiency in the use of inputs to produce output, and this was is driven by output growth, given that outgrowth during the period understudied outpaced input growth. Considering the effect resource allocation on sector-level productivity growth, our findings show that resource allocation between farms appeared to have a negative effect on the dairy sector-level productivity growth, and the sector productivity growth has been largely driven by on- farm technology progress. The main drivers of farm-level productivity of dairy farm sector include: farm size, milk yield, stocking density, capital to labour ratio and shared of hired labour, purchased feed per cow, labour input per cow, share of direct payment in farm output.

Overall, the findings of this study have shown a variety of pathways to improving productivity growth of dairy sector in NI. For example, promoting on-farm innovation technology and farm management, and also providing a policy environment that will remove any market or institutional barriers so as to facilitate better efficient resource allocation between Northern Irish dairy farms as a whole.

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Presenters profile

Kehinde Oluseyi Olagunju is an Agricultural Economist at AFBI Office Newforge Lane, Belfast. His research interests include quantitative techniques, production Economics, and land economics. He is recently involved in research projects on - the impact of decoupled payments on agricultural production; trends and drivers of productivity of dairy sector in Northern Ireland; land capitalization of Single Payment Scheme in Northern Ireland.

Economic Analysis of International Markets for Georgian Wines

Lado Arabidze

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Abstract

Georgia is the birthplace of winemaking with the 8000 years of history. After the Russian wine ban in 2006, Georgian wine industry had a big transformation. Country has started to diverse international markets. For the last 15 years exporting destinations for the wine has changed a lot. Some of the western (USA, EU countries, etc.) and Eastern (China, Japan) countries have started to import local wines. Statistics from recent years have shown that Georgian wine has both Quantity and Value increase on the international markets. In 2018, Georgia has exported 86.2 Million bottles of wine in 53 countries of the world. As the demand increases the production of the wines are changing really fast.

Article will provide information about modern situation of Georgian wine exports. It will include analysis of wine statistics provided from the International Organization of Vine and Wine, Georgian National Wine Agency, etc. Also it will provide information about Georgian Traditional winemaking potential that is on the increase at the moment. The objective of this study is to analyse Georgian Wine situation on international markets and to research the potential that the country has. We will mainly focus on Georgian wine statistics from 2006 to 2018. We will use data from international and local organizations. Aim is to demonstrate that Georgian wines have more potential internationally.

Keywords: Georgia, Economic analysis, International market, Export, Wine.

Presenters profile

Lado Arabidze started studying in 2012 at Agricultural University of Georgia – Bachelors of Viticulture and Enology faculty. After graduation in 2016 Lado started working at Shilda Winery as an assistant winemaker and continued studying at Telavi State University on Masters of Alcoholic and non-alcoholic Beverages. In 2018 Lado finished a masters and started a Phd of Economics at Georgian Technical University, while working in Portugal at Casa Relvas. Lado is currently the Chief winemaker at Chateau Buera (LTD. Lopota) in Georgia. In 2019, Lado attended the International Workshop in Georgian Technical University – Globalization and presented an article on Innovations in Agriculture – International Experience.

Smallholder Farmers' Participation in Agricultural Cooperatives: Does it matter for Improving Technical Efficiency in Nigeria?

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Abstract

Improving agricultural productivity and technical efficiency among smallholder farmers is widely understood to be an important strategy for sustainable rural development and poverty alleviation in developing countries. However, these farmers are mostly faced with multiple production and marketing constraints such as such as high transaction costs of accessing inputs and output markets, unavailability of modern technologies, and poor access to credit facilities. To help address these challenges, mechanisms to encourage the formation of agricultural cooperatives have been promoted as a potential policy instrument by donor agencies and private agribusiness companies, with the overarching aim of increasing agricultural productivity in developing countries.

Using a survey data of 2,216 smallholder maize farmers from rural Nigeria, this study examines the impact of agricultural cooperative membership on farm technical efficiency (TE). Our contribution to the literature is in the use of a recently developed selectivity corrected stochastic production frontier model with propensity score matching to address possible self-selection biases arising from both observable and unobservable factors.

The empirical results show that TE for cooperative members ranges from 75 to 86 per cent and that for non-members ranges from 72 to 81 per cent, depending on how biases are accounted for. In addition, the efficiency levels of both members and non-members of cooperatives appear to be underestimated if the selectivity bias is not properly addressed. Our findings conclude that the average TE is consistently higher for cooperative members relative to their counterparts who produce and market maize individually, highlighting the positive role of contemporary agricultural cooperatives in promoting efficient usage of production inputs.

The important role of farmer groups in enhancing smallholder farm technical efficiency, as evidenced in this paper, calls for continuous and increased support from government, development agencies, and private agribusiness companies in cooperatives formation when implementing agriculture and value chain development interventions.

Presenters profile

Kehinde Oluseyi Olagunju is an Agricultural Economist at AFBI Office Newforge Lane, Belfast. His research interests include quantitative techniques, production Economics, and land economics. He is recently involved in research projects on: the impact of decoupled payments on agricultural production; trends and drivers of productivity of dairy sector in Northern Ireland; land capitalization of Single Payment Scheme in Northern Ireland.

Environmental regulation and economic efficiency: Evidence from China's coastal areas

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Abstract

China's commitment to building the country into a maritime power has seen a rapid growth in its marine economy in recent years. In the meantime, increasing concern over environmental degradation has made the government to shift attention from marine development to marine ecosystem protection by formulating more environmental policies. Indeed, China is facing a trade-off as environmental protection and economic growth can be conflicting. There has been a long-standing debate between traditional views and well-known Porter Hypothesis (PH) over the impact of environmental regulation on the competitiveness and efficiencies of firms and industries. Aiming to obtain empirical evidence of the possible impact, this paper uses the Super-Efficiency Slacks-Based Measure (SE-SBM) model to calculate economic efficiency considering undesired outputs and the system Generalized Moment Method (GMM) to examine the relationship between the two variables, using data from 11 provinces and cities in China's coastal areas. The results seem to support the presence of the PH in Chinese marine economy and show a U-shaped relationship between environmental regulation and economic efficiency. In the end, the paper puts forward some recommendations for policy makers.

Keywords: environmental regulation; economic efficiency; Porter Hypothesis (PH); SE-SBM model; panel data.

Presenters profile

Hairong Mu is a senior lecturer in Economics at Harper Adams University. Before joining Harper, Hairong got her PhD from the University of Southampton and then worked at the University of York as Post-Doctoral Teaching Fellow. Her research interests have two major themes: the first lies in microeconomics in general with focus on competition policy and regulation. The second theme is pedagogical research with focus on education of economics.

On-farm diversification of rubber farming and its economic impact: A systematic review

Iona Yuelu Huang[A], Katy James[A], Nithicha Thamthanakoon, Nithicha Thamthanakoon, Pim Pinitjitsamut, Nararat Rattanamanee, Montchai Pinitjitsamut, Sophon Yamklin, and James Lowenberg-Deboer[A]

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Abstract

Thailand is the world's largest natural rubber producer and exporter and the majority of Thai rubber growers are small-scale farmers. Many of smallholder farmers face poverty because of price volatility for rubber on world markets. When the price of rubber is low, the income of small-scale rubber farmers declines because a large majority cannot manage risk through diversification. This study aimed to identify evidence of on-farm practices to diversify rubber farming as a means to improve economic sustainability based on a systematic search of 14 key academic databases and 17 natural rubber related organisation websites.

After removal of duplicates, a total of 6341 articles were identified from the period of 1985 to 2018. Six reviewers screened the titles and abstracts against inclusion criteria resulting in 107 potentially relevant articles for full text screening. After full text assessment, 43 articles were excluded, 64 studies were subjected to qualitative synthesis. Those studies were reported from 10 countries from Asia (n=55), West Africa (n=7) and South America (n = 2). The studies were analysed in detail identifying: on-farm diversification method; synergies achieved; barriers and facilitators to uptake of on-farm diversification.

Intercropping was found to be the most reported on-farm diversification practices, followed by multiple cropping and vertical on-farm diversification (i.e, adding value to rubber). The most commonly studied intercrops with rubber were crops grown for food, including tree (e.g. fruit trees) and non-tree (e.g. cassava) crops. Fewer studies investigated diversification through timber or livestock production. Majority of the farms studied were small farms and only 2 were relatively large estates (12 and 28 ha).

Key barriers to uptake of diversification included: lack of skills and knowledge, labour shortage, insufficient capital for investment, and instability of market price for other crops. Synergies achieved through intercropping included yield and nutrient acquisition advantages found in some intercropping systems, and labour saving for weeding. Enhanced access to market for other crops and improved agricultural extension services so that farmers can gain the knowledge and skills required for diversification were found to be key facilitators.

This synthesis was limited to publications in English and those available to the research team. More detailed analysis of the economic outcomes reported in the studies is in progress to identify the economic impacts of on-farm diversification.

Presenters profile

Dr Iona Yuelu Huang is a senior lecturer at Harper Adams University. She is the course coordinator for MSc International Agribusiness & Food Chain Management. She has been a member of several research teams, including AgroCycle (a Horizon 2020 funded project on valorisation of agri-food waste) and the ongoing Newton Fund Institutional Links project "Sustainable Agribusiness Model for Poverty Reduction among Thai Small-scale Rubber Farmers". Her research interests fall into the broad categories of governance of supply chain, agribusiness decision making and economic impact of agri-tech and innovation adoption.

Diversification activities practiced by rubber farmers in Southern Thailand: A linear programming model for economic optimization

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Abstract

Diversification has long been recognised as one of the agribusiness strategies to manage price risk. Currently, nearly 90% of Thai rubber plantations are still monocropped. Potential on-farm synergistic diversification strategies include fruit and vegetable production, alternative tree crops (e.g. coffee, cacao, timber), and livestock (especially goats or poultry) rearing. This study aimed to develop a model to support the 1.1 million small-scale rubber farmers in Thailand, 79% of all Thai rubber farmers, to manage the risk of rubber price volatility and optimise land use.

Data were collected through detailed face-to-face semi-structured interviews with 20 rubber farmers who have practiced on-farm diversification in two southern provinces of Thailand (Chumphon and Surat Thani). Based on monthly labour inputs, materials input, outputs, and physical and climate constraints, a series of scenario-based modelling of economic optimisation of land use and on-farm diversifications have been developed for small-scale rubber farmers.

Preliminary analysis suggests that in Southern Thailand the potential for intercropping rubber with other species is modest because rubber plantations are usually densely planted to maximize latex production and to reduce wind damage to trees. Consequently, few commercial crops can grow under the rubber trees and most diversification is multi-cropping with other species on nearby fields. There is some potential for farmers to capitalize on complementary labour requirements. For example, rubber can be tapped all year round in Southern Thailand, but some farmers reduce tapping at the beginning of the rainy season in March, April and May which is the time when vegetables, pineapple, fruit trees, coconut and oil palm can be planted. The research will also use a Target MOTAD model to examine the portfolio effect of the price patterns for the various crop and livestock options.

It is hoped that, as a result of this project, 1) Thai smallholder rubber producers know more about their options for managing price fluctuations and become more resilient, and 2) The Rubber Authority of Thailand (RAOT) and other Thai rubber sector stakeholders have additional tools to inform small-scale rubber farmers for evidence-based decision making.

Presenters profile

Dr Montchai Pinitjitsamut is a lecturer in Agricultural and Resource Economics, Faculty of Economics, Kasetsart University, Thailand. Dr Pinitjitsamut has over 20 years of experience in Research and consulting. He has developed a Global Forecasting Model for Natural rubber price, demand and supply, in 2016, which was widely referenced in Thailand, Indonesia, Malaysia, China and others. He is one of the project managers for the ongoing Newton Fund Institutional Links project “Sustainable Agribusiness Model for Poverty Reduction among Thai Small-scale Rubber Farmers” (SAMPRR). His research interests are in natural rubber economics, Energy economics, Economic development and Computable General Equilibrium.

Dr Sophon Yamklin a lecturer in Agricultural and Resource Economics, Faculty of Economics, Kasetsart University, Thailand. He is a member of Management Committee of Bachelor of Agribusiness at KU. Dr Sophon Yamklin has more than fifteen years’ experience in designing business model and business plan for agribusiness entrepreneur. He is a team member of the Newton fund Institutional Links project SAMPRR. His research interests are in business model innovation, design thinking in agribusiness, agricultural entrepreneurship, customer empathy, customer insight analysis, innovation foresight, elderly segmentation in agricultural and food business, agribusiness innovation.

Dr Nithicha Thamthanakoon is lecturer in Agricultural and Resource Economics, Faculty of Economics, Kasetsart University, Thailand. She is also Assistant Dean for Student Affairs at Faculty of Economics. She obtained her PhD at Harper Adams University in September 2019. She is a team member of the Newton fund Institutional Links project SAMPRR. Her research interests are in agricultural marketing, consumer behaviour and farmers decision making

Bovine meat supply chain in Lithuania

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Abstract

During the period from 2010 to 2017, the Lithuanian cattle production sector experienced dramatic transformations. The number of dairy cows dropped by nearly one fourth, while the total population of live bovine animals decreased by nearly one tenth. Many Lithuanian farmers exited the dairy production and shifted to bovine meat production or other types of farming. The situation was determined by milk supply chain functioning problems, i.e. purchase prices for raw milk were very low and small farmers were not able to cover production costs. However, the situation in meat production industry offered higher diversity of business models and farmers were less dependent on local stakeholders. The paper is aiming to investigate the price transmission of bovine meat supply chain in Lithuania. The study applies the Johansen co-integration and the Granger causality tests, error correction model. The Johansen co-integration test shows that between farm and retail prices there is at least one co-integrating equation and variables move together in the long run. The Granger causality test shows that price runs from farmer to retailer, and in the short run farmers lead pricing. The error correction model shows 24.68% speed of adjustment towards the equilibrium, i.e. the market recovers in four weeks.

Keywords: Agriculture, meat, price transmission, supply chain

Presenters profile

Nelė Jurkėnaitė is a Senior Researcher at the Lithuanian Institute of Agrarian Economics since 2014. She has graduated from the Vilnius Gediminas Technical University and has a Master of Science in Management and Business Administration. She prepared a doctoral thesis at Vilnius Gediminas Technical University. In 2010, she became a PhD graduate in Social Sciences (Management and Administration). The main research areas: agricultural policy, farm viability, price transmission, and supply chains.

Dimitrios Paparas is a Senior Lecturer at Harper Adams University since 2013. He has graduated from the Aristotle University, Thessaloniki and has an MSc (Kingston) in Business Economics and Forecasting, an MSc (Aristotle) in Agricultural Economics and a MA (Keele) in Education. He got his PhD (UEL) in Fiscal Policy and he worked as a lecturer in Kingston University, University of East London and Coventry University. Dimitrios is currently a Senior Fellow in the HEA. His main research interests are agricultural economics, agri-tech economics, educational economics, and macroeconomics.

A Study of the Relative Relevance of the Factors that Determine Beef Finishing Farms' Profitability in Developing and Developed Countries

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Abstract

Previous research have identified a number of factors that affect profitability in feedlots such as beef price, feeder cattle price and feed costs. However, empirical studies have been developed in specific countries and there is lack of data providing cross-country information. Therefore, this article extends traditional research to compare countries and identify differences between developed and developing nations. In order to contribute in filling the gap, a linear regression was developed with data from different countries to identify the relative importance of each factor. The analysis shows similar findings with previous research and identified price volatility as an important factor that have not been identified before. When comparing developed and developing nations, it was found that wages have more impact on developed nations whereas the opposite applies for volatility. Moreover, some feeding factors were identified as more relevant in some countries than in others which will be explained alongside this thesis as well as the implication of these findings for the global intensive beef finishing industry.

Presenters profile

Antonella Riani, from Uruguay, studied veterinary sciences at the University of the Republic in Montevideo, and moved after graduating to work with farmers in her hometown. Antonella has specializations in reproduction and the job was mainly focused on improving reproductive parameters of beef cattle. After working for some years, she moved to the UK to study a Masters in International Agribusiness at Harper Adams University, because of a desire to move from the production side of farming to being involved with the global agricultural value chain. Nowadays Antonella is working at Bunge SA in Barcelona, a multinational company that trades agricultural commodities and her objectives are to keep learning and developing my professional skills within the company.

Relationship between Agriculture Expenditure and Agriculture Growth in Rajasthan

Kirandeep Kaur

Statistical Officer, Planning Department Government of Rajasthan, Rajasthan, India

Abstract

The purpose of the present study is to analyse the dynamic link between Agricultural government expenditure and Agricultural growth in Rajasthan state with the time series data from 1980 to 2018. The findings of the Johansen and Julselius test for cointegration confirmed that there is one cointegration vector relationship between the total expenditure and total NSDP of the state and there was no cointegration found between Agriculture Expenditure and Agriculture NSDP, Agriculture Expenditure and Total NSDP and Agriculture Expenditure and Total Expenditure. The present study employed different model specification for different functional form. The causality analysis of the Vector Error Correction Model revealed that there is Uni-direction long run as well as short run causality from total NSDP to Total Expenditure. The results of VAR analysis showed that the One-way causality from total NSDP to Agriculture Expenditure and from agriculture expenditure to total expenditure. The findings of the ARDL Model state that there is long run cointegration between agriculture expenditure and agriculture NSDP of the state. The study concluded that there is short run causality between agriculture expenditure and total expenditure and the agriculture expenditure and total NSDP. The study suggest that government should more focus on capital expenditure on agriculture rather than the current expenditure in agriculture so that the long-term growth can be increase in agriculture sector.

Keywords: Agriculture Expenditure, Agriculture Growth, Total Expenditure

Managers' perspective on the implementation of Sustainable Supply Chain Management (SSCM): the case of the retail supermarket sector in Greece

Eleni Sardianou[A] and Efthalia Christou[B]

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[B] *NATO Headquarters, Boulevard Leopold III B- 1110, Brussels, Belgium*

Abstract

This paper builds upon the concept of sustainability in the logistics strategy of firms, the so-called Sustainable Supply Chain Management (SSCM). SSCM is a management strategy that incorporates the triptych of environment, society and economy to the supply chain. The purpose of the present paper to empirically investigate whether supermarket sector managers adopted SSCM practices during a recession in order to retain their competitiveness and increase their performance. In particular, we aim to analyse the obstacles and the drivers that stimulate managers of supermarket branches to adopt SSCM practices. For that purpose, a closed type questionnaire was distributed in either managers or deputy managers to a mixed sample of supermarket chains in Athens, Greece, via door-to-door method. Empirical findings of the research suggest that branch's managers adopt several sustainable supply chain practices mainly in relation to food products. However, the research provides evidence of the existence of barriers and drivers such as legislation, interior drivers, competitive advantage, supply chain, social drivers, sustainability drivers and other drivers. Results indicate that from a management perceptive view, the drivers to implement SSCM combines both organizational-oriented and external criteria. Managers also declared that the current legislation in Greece as well as in the European Union are drivers that can impact the implementation of SSCM. The commitment of CEO (or equivalent Staff) is also an important factor that drives to SSCM in terms of the interior drivers. A driver that brings a competitive advantage to the chain such as the provision of new opportunities seems to be a vital factor to implement the SSCM practices in the supermarkets. Concerning the supply chain, the businesses' encouragement of which are suppliers to the supermarket, it is slightly influences the adoption of the SSCM. Also, significant social drivers are considered to be the maintenance of society's view that the business is environmental or responsible to society, and the public opinion or expectations. In regards with the sustainability drivers, the effort of employees to imply SSCM and the exchange of ideas into the chain are very important drivers for the SSCM. Last, drivers (such as exports and the sales to foreign customers) that were not in correspondence with any other driver category given by the references were characterized as other drivers. To manager's view, these drivers have also an influence on the adaptation of the SSCM in the retail supermarket sector in Greece.

Keywords: Retail businesses, Supply chain management, SSCM Drivers.

Presenters profile

Eleni Sardianou is Assistant Professor in the Department of Home Economics and Ecology, School of Environment, Geography and Applied Economics, Harokopio University (HUA) Athens, Greece. She holds a Master of Science in Sustainable Development focusing on Consumer Behaviour and a Ph.D. Degree in Environmental Economics. She teaches environmental economics, energy economics, statistics and econometrics. She is a member of the Laboratory of Economic and Social Analysis of Family and Consumer Issues. Her research interests include: Quantitative analysis of energy economics, Consumer behaviour and Energy Policy, Sustainability performance of Firms, Sustainability and environmental policy. Her research work has been published in more than 20 papers in refereed journals and has been cited in more than 900 papers (h-index 9).

Thalia Christou occupied a Bachelor degree in Economic Science by University of Pireaus in 2015. She completed her postgraduate studies in Sustainable Development at Harokopio University in 2016. During and after her studies, she had been working in various business-oriented fields in the private sector. She also worked as an intern in the Embassy of Greece in Budapest. She is currently working as a Civilian Staff with the focus on project management and administrative support in NATO Headquarters in Brussels. She is a native speaker of Greek. She also speaks English and has an elementary knowledge of Russian.

The impact of public policies on smallholder farmers: The case of tobacco reforms in Malawi

Ian Kumwenda

Harper Adams University, Newport, Shropshire, United Kingdom

Abstract

Tobacco is one of the most significant crops in Malawi's economy. It is the single largest source of export earnings, contributing 50-62 percent of total exports. The tobacco crop employs around 12 percent of the population, and accounts for about 13 percent of GDP. This crop also accounts for about a quarter of Malawi's export base. As a result, tobacco is not only Malawi's main export earner but also of key importance for rural households' incomes and food security.

This paper examines supply response of tobacco to policy reforms using three models (yield, area and export) in order to determine short run and long-run coefficients. Various methods are used that include unit root test with structural breaks; Granger Causality Tests; and Autoregressive Distributed Lag (ARDL) approach to Error Correction mechanism (ECM) using bound testing procedure.

The results of the long-run yield model reveal that tobacco yield variable in the previous year was highly significant at 0.01 percent. The coefficient of fertilizer price is negative and significant at 10 percent indicating an increase of price leading to a decrease in yield. Rainfall is highly significant with expected sign. The Error Correction Term (ECT) is estimated at (-0.50). The area model revealed that the area under tobacco in tobacco in the previous year was highly significant at 0.01 percent. The price of tobacco was significant indicating an increase of price leads to an increase in area under tobacco. The price of maize was highly significant but taking a sign which was not expected. It should have taken a negative sign.

The liberalization of tobacco was significant taking on a positive sign. However, the coefficients of long-run model are all less than unity. The ECT was equal to -1.21. For the export model, the long-run coefficients showed that previous years of tobacco export was – 0.54 and significant at 0.01 percent. The price of tobacco was significant at 0.01. The real effective exchange rate and gross capital formation were significant at 0.05 percent. The coefficient of ECT was estimated at -11.75. The short-run coefficients were less than unity implying that they are inelastic in short-run.

It is recommended that an improved policy package that comprises economic, non-economic incentives and effective transmission mechanism is a critical role to elicit a better response of smallholder farmers in Malawi.

Presenters profile

Ian Kumwenda is an agricultural economist with more than 25 years of experience in agricultural development including more than 20 years working across the Southern African Development Community (SADC) and COMESA on agriculture-related policy. From 1981 to

2008, he worked for the Malawi Government in Ministries of Agricultural and Food Security and Economic Planning and Development and the Malawi Agricultural Sector Investment Program (MASIP). He has various publications in the field of his expertise. He is pursuing a PhD in Agricultural Economics with Harper Adams University. He holds a Master of Science degree in Agricultural Economics from University of Aberdeen and a Bachelor of Science degree in Agriculture from the University of Malawi.

Implementing blockchain technology in a poultry supply chain: what do stakeholders say?

Sophie Thornton, Ourania Tremma and Luis Kluwe de Aguiar

Harper Adams University, Newport, Shropshire, United Kingdom

Abstract

Blockchain technology remains in its infancy since its introduction in 2008 (Litke, 2019). So far, its application and uptake has been driven by the perceived benefits of blockchains have in increasing trust, traceability, improving food safety and reducing administration time (Verhoeven et al., 2018). However, there is little research regarding implementation of the technology within the agricultural supply chain particularly in the United Kingdom. There this study explores the potential role of blockchain technology within the poultry supply chain.

The literature review highlighted key advantages, disadvantages and barriers to blockchain technology. A mixed method was used to collect information via a questionnaire survey aimed at members of the broiler and laying industry. That was followed by in-depth semi structured interviews. Quantitative statistical tests were carried out including Man Whitney U test, Chi squared test, Freidman test, Spearman's rank correlation, and a Multiple Regression test for the quantitative data analyses. Thematic analysis was used to interpret the qualitative data set revealing the frequency of words which was displayed as a word cloud and a concept map to better visualize the relationships between opinions and the topic.

The results show that Food Safety, Traceability, and a New Supplier System have emerged as major factors for stakeholders, despite demographic differences. The Mann-Whitney U test indicated a higher demand within the broiler industry than the laying industry for a system to increase education for consumers and a new system to tell the story of food production (p= 0.013 and 0.045 respectively). However, the findings illustrated that stakeholders have a limited knowledge of blockchain. In terms of feasibility, the crosstab calculations illustrated that poultry stakeholders believe blockchain is feasible in the long term. The Freidman test showed traceability to be the most important factor to participants, and increased purchasing behaviour as the least (X2 (2) = 92.496, p=0.000). The thematic analysis showed traceability to be the greatest advantage of blockchain. In contrast, the main disadvantage of blockchain technology is financial cost. Lastly, the thematic analysis showed the main implementation factors to be data ownership and cost.

Concluding, blockchain technology will benefit the poultry supply chain, despite the disadvantages such as the lack of data consistency. Disadvantages can be overcome by a variety of methods, such as auditing the blockchain technology. Likewise, other barriers need to be overcome if uptake is to increase, e.g. data and cost implementation – the key barriers - must be decided before implementation. As previous studies have shown, this can be achieved via an open data system or hybrid blockchain. Due to the variation in stakeholder opinions it is clear there is no best practice or ideal framework for blockchain technology in the poultry industry. Nevertheless, an efficient blockchain requires all parties to understand the technology and recognize the value of sharing the data.

Presenters profiles

Luís Kluwe de Aguiar works at Harper Adams University in England where he is Course Manager for the degrees in the Department Food Technology and Innovation. He is Senior Lecturer in Food Marketing and Sustainability. He has graduated from the Federal University of Rio Grande do Sul (UFRGS/Brazil) and has an MSc (City) in Food Policy and an MSc (London) in Agricultural Economics. He has extensive professional experience working for private and government organisations both nationally and internationally with roles in policy monitoring and advisory, management, sales promotion, education and training as well as consultancy. Has work experience in various countries including China, France, Israel, Brazil, Saudi Arabia, Viet Nam, Laos, Venezuela to mention some.

Ourania Tremma is a Lecturer in Research Methods & Statistical Analysis at Harper Adams University – UK. She holds a 5-year degree in Agricultural Economics (MSc integrated), an MSc in Agricultural Economics and Trade, an MSc in Economics and a PhD in Agricultural economics and Price transmission from the Aristotle University in Greece. Her research interest focuses on price transmission and asymmetries on a spatial, vertical and horizontal level as well as price volatility and agricultural policy.

Students' perceptions of future technology use in agriculture: A NZ UK comparison

Eva Schröer-Merker[A] and Victoria Westbrooke[B]

[A] *Harper Adams University, Newport, Shropshire, United Kingdom*

[B] *Lincoln University, Canterbury, New Zealand*

Abstract

Agricultural systems are currently experiencing a wave of new technological developments. The technology ranges from plant or animal recognition software and smart irrigation using sensors to the development of E-fences. Technology such as virtual trading venues and methods using block-chain are also currently in development (Lin et al. 2017). These technologies could lead to large and potentially disruptive changes in agricultural systems (Small, 2017).

However, the adoption rates of new technologies has been highly variable (Miller, Griffin, Ciampitti, & Sharda, 2018). Adoption rates of technology can be estimated based on specific attributes of the technology and how it will be used (Kuehne et al., 2017), though this can be difficult with new and emerging technology. An alternative approach which will be used in this study, is the Theory of Reasoned Action (Fishbein & Ajzen, 1975). This theory 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.

Presenters profiles

Eva is a Lecturer in Farm Business Management and Course Tutor for Business Courses at Harper Adams University. She has a keen interest in farm profitability and agricultural technology. Before joining Harper, Eva was a Senior Tutor in Farm & Agribusiness Management at Massey University, New Zealand, and leading the 'Farm Tools' project for the Centre of Excellence in Farm Business Management (CEFBM), keeping up to date with and speaking about the future of farming in view of technology. Prior to that, Eva headed up the International Farm Comparison Network's (IFCN) Dairy Sector Analysis team at the Dairy Research Centre in Kiel, Germany.

Dr Victoria Westbrooke's research area is 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 I have been a dairy farm consultant in both NZ and the UK and have also worked in agricultural research. Currently I'm based at Lincoln University in Canterbury, NZ where I teach farm management at both undergraduate and post graduate levels.

Precision Agriculture: Are multi-cut silage systems profitable for UK farming systems?

Eva Schröer-Merker and Wyn Morgan

Harper Adams University, Newport, Shropshire, United Kingdom

Abstract

Dairy farmers in the United Kingdom (UK) are increasingly moving towards more frequent cutting of silage (AHDB, 2018). Multi-cut systems are defined by up to six cuts of silage with approximately four-week gaps between cuts. The first cut is about two weeks earlier (end April) than the traditional system with two to three cuts of silage. The aim is that while individual cuts are lighter, overall yields, and resulting Metabolisable Energy (ME), will be equal or higher than the traditional system. Multi-cut systems are already widely used in The Netherlands, Denmark and The United States of America (Farmers Weekly, 2017). Anecdotal evidence indicates that farmers often don't implement a complete multi-cut system, but are somewhere between traditional and multi-cut, thus potentially not generating the full benefits of either.

Presenters profiles

Eva Schröer-Merker is a Lecturer in Farm Business Management and Course Tutor for Business Courses at Harper Adams University. She has a keen interest in farm profitability and agricultural technology. Before joining Harper, Eva was a Senior Tutor in Farm & Agribusiness Management at Massey University, New Zealand, and leading the 'Farm Tools' project for the Centre of Excellence in Farm Business Management (CEFBM), keeping up to date with and speaking about the future of farming in view of technology. Prior to that, Eva headed up the International Farm Comparison Network's (IFCN) Dairy Sector Analysis team at the Dairy Research Centre in Kiel, Germany.

Wynn Morgan studied Agriculture at Aberystwyth University and then farm management at Seale Hayne Agricultural College. Following Seale Hayne he worked for Promar as a consultant (dairy and finance) before establishing an outdoor pig breeding partnership in Wiltshire. Following the sale of the pig business Wyn lectured at Writtle College for a number of years and then briefly at Royal Agricultural University before being employed by Harper Adams University in 2012. During his academic career, he has also delivered animal husbandry modules and has overseen university commercial units. Present appointment: Senior Lecturer in Farm Business Management, Course tutor BSc agriculture 1st year, Harper Adams University.

Attitudes, expectations and reality of precision tech agriculture in the UK

Eric Siqueiros[A], Trisha Toop[A], and Simon Thelwell[B]

[A]*AGRI Project, Harper Adams University, Newport, Shropshire, United Kingdom*

[B]*Land, Farm & Agribusiness Management Department, Harper Adams University, Newport, Shropshire, United Kingdom*

Abstract

This project aims to gain an understanding of farmers' attitudes towards Precision Farming (PF), current and future. It also explores the expectations that farmers have towards PF and their experience once they adopted it. The study was originally directed to the Midlands and North West regions of the UK. The target area of the survey consisted of 8 counties. Nevertheless, the survey was extended in order to consider all counties in the UK. Therefore, the participant farms are located in 52 Counties. A survey was designed and sent to farms located in the UK. The average farm size that completed the survey was 504 ha. 72 % of the farms are either mainly or wholly owned, while 60% work with cereals or mainly cereals. Autosteer is the Precision Farming technology that is most used currently. The most expected benefits fall into the economic category (reduce costs). Overall, 95% percent of farms will at least consider investing in PF as a possibility. When asked if PF is a very important factor in the future of sustainable farming, only 9% disagree. However, 50 % agreed that good farmers will be able to use traditional methods to remain competitive. It was reported that with their current use of PF they are experiencing some improvements. Compatibility and connectivity are the two aspects of the technologies that participants experience most of problems. This was confirmed with the answers of the open question about problems. The most common terms were: Software, signal and systems. Conversely the most common terms when participants described their experience with PF were: good, time, cost. Moreover, 56 % of the farmers would definitely consider investing in precision farming, while 39 % will consider it as a possibility. This shows that overall farmers have positive thoughts towards PF and 95 % would consider it at least as a possibility.

Presenters profiles

Eric Siqueiros currently works as a Post Doctorate Researcher at Harper Adams University in the AGRI project. Eric obtained his PhD from Newcastle University and his research was focused on "Thermal and waste Management in the Food Industries". Previously he worked during 5 years as a process engineer for a Flavours processing company.

Trisha Toop is an Academic Engineering Expert within the AGRI project, working to assist companies with innovation in the agri-tech and agri-food sectors. Trisha is an interdisciplinary researcher combining biology, biochemistry, engineering and mathematical modelling. Specialties: Interdisciplinary Research, Biochemistry, Mechanical / Manufacturing Engineering, Mathematical Modelling, Life Cycle Assessment and Project Management.

Prior to joining Harper Adams in 2010, Simon Thelwell worked for a London based food and farming consultancy company specialising in procurement of raw materials from farms into major food processors/manufacturers, he has been involved in improving supply chains in dairy, cereals, horticulture and the beef and sheep sectors. Simon has worked on consultancy projects spanning in the UK, Europe and internationally in the US and most recently China.

Business model alternatives for post adoption of precision agriculture in the UK

Eric Siqueiros[A], Trisha Toop[A], and Simon Thelwell[B]

[A]*AGRI Project, Harper Adams University, Newport, Shropshire, United Kingdom*

[B]*Land, Farm & Agribusiness Management Department, Harper Adams University, Newport, Shropshire, United Kingdom*

Abstract

A novel approach for supporting adopters of Precision Farming (PF) was evaluated. A survey was designed and sent to farms located in the UK through different channels. In total 186 farmers completed the survey online. The first part of the survey was focused on farm location, size, type and tenure. In the second part, questions were directed towards the use and views on precision farming. Finally, the training provided and assistance post adoption was evaluated in the last section of the questions. The aim was to understand what type of assistance on PF farms find more convenient. Also, what sort of scheme or subscription they would be willing to join. The fact that the diversity in size and type was considered helped to understand if particular types of farms are more interested in PF. Similarly, it was noticed throughout the survey that smaller farms showed both, interest and experience in using PF. Most of the participants are familiar with YouTube and mobile apps. In some cases, they are already used for farming purposes. This is important to consider when offering new solutions. As it would be easier for the users to use technologies that are already familiar to them. The training that is currently provided for PF is mainly when the equipment is bought. Face to face training, phone assistance and video based are the preferred methods for assistance. Participants also mention that in most cases they would access the assistance on a monthly basis or less often. This was confirmed when they expressed that their preferred subscription option is on an annual basis. Monthly subscriptions and a charge per day of use were also considered as acceptable. Consequently, they would consider to pay the highest fee (£278) for the annual option.

Presenters profiles

Eric Siqueiros currently works as a Post Doctorate Researcher at Harper Adams University in the AGRI project. Eric obtained his PhD from Newcastle University and his research was focused on "Thermal and waste Management in the Food Industries". Previously he worked during 5 years as a process engineer for a Flavours processing company.

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Do pupils in Greece have good Health Related Quality of Life? How the Mediterranean Diet affects it

Stamatina Papadaki

Department of Public and Community Health, University of West Attica, Med, MSc, Phd Candidate

Abstract

The aim of this paper is to evaluate adolescents' Health Related Quality of Life (HRQoL) and its association to the Adherence to the Mediterranean Diet (AMD). It is very important for family members and people who work with adolescents, to realize individual well being and the association with an adolescent's diet. Recent years Greece is a country that has a low adherence to the Mediterranean diet and this is also very obvious between children and adolescent. Since there are some evidence that adherence to the MD affects components of the perceived Health Related Quality of Life, further investigation is needed. Empirical analysis was based on a cross- sectional, school- based study we collected data from 525 adolescents (boys; girls) between 12-18 years old, living at Athens and Heraklion Grete. The research took place during March-April 2015. Standard anthropometric measurements were taken and obesity was assessed using the International Obesity Task Force (IOTF) cut off points. The KIDMED test was completed with score> 8 indicating an optimal MD and perceived HRQoL was assessed by the KIDSCREEN-27 questionnaire for children and adolescents. Analysis included Chi-square test and Student t test for the association between variables. Linear regression analysis was used to identify the determinants of AMD. A 2- sided P- value of less than .05 was considered statistically significant. Results reveal that perceived HRQoL is associated with gender, age, BMI and the adherence to the Mediterranean Diet.

Presenters profile

Stamatina Papadaki is a PhD candidate at the Department of Public and Community Health, University of West Attica. She holds a Master of Education in Socio-biology, Neurosciences and Education and a Master in Science in Environment & Health from the National and Kapodistrian University of Athens. Her PhD research emphasizes on eating habits and lifestyle characteristics of adolescents in relation to the prevalence of obesity.

Risk averse and its influence on farmer acreage decision making behaviour

Debin Zhang[A], Ping Qing[B] and Yeming Gong[C]

[A] *College of Public administration, Huazhong Agricultural University, China*

[B] *College of Economics & Management, Huazhong Agricultural University, China*

[C] *EMLYON Business School,23 Avenue Guy de College,69134 Ecully Cedex, France*

Abstract

This work explores how risk averse influencing acreage decision making behaviour for different kinds of farmers. We first develop an acreage decision making model focusing on risk aversion, which derives expected utility. Using this optimisation model, we established a deduction method to inference a risk aversion ratio. Next, with the developed method on National vegetable survey data from China, risk aversion ratio results have been derived and discussed with specific regional characters. We find that to deduct the risk preference of a farmer using historical acreage decision making data is feasible; large size farmers have a higher risk averse than small and medium size farmers; while that of large farmers is primarily affected by the fixed investment.

Presenters profile

Debin Zhang, PhD, Associate Prof. in School of Public Administration, Huazhong Agricultural University, China. Debin's primary research interests includes fresh produce supply management research and farmer cooperatives research. Debin is the Principal Investigator of two National Science Foundation of China projects.

The Nigerian Agricultural Sector Model (NASM): A Sectoral Agricultural Policymaking Tool & An Empirical Model for Optimizing Food Production and Boosting Food Security in Nigeria

Ndukwe Agbai Dick and Paul Wilson

DAES, University of Nottingham, Sutton Bonington Campus, United Kingdom

Abstract

Agricultural production provides an opportunity for Nigeria to diversify its economy. Nevertheless, a sectoral analysis of the agricultural sector's potential has yet to be formally undertaken. We address this gap by proposing an empirical model that provides evidence-based policy recommendations on how agricultural development policies can be pursued in Nigeria in order to create employment and boost food security, income, foreign exchange and rural development.

Anchored on a partial equilibrium model framework, this study develops and applies a regionalised Nigerian Agricultural Sector Model (NASM) to replicate existing crop production, marketing and consumption activity in Nigeria. This model provides an opportunity to empirically describe and understand the Nigerian crop production system and the inherent economics of production, while generating regional cropping patterns, land use and domestic food supply systems. Moreover, the NASM provides an analytical framework that can be adapted for agricultural development policymaking in other countries.

Results reveal the profitability of Nigerian crop farming sub-sector, covering 21 different major food and cash crops while simultaneously estimating the regional competitive advantage in domestic crop production and produce exports, and are of interest to Nigerian agricultural policymakers, interested investors, and rural development researchers.

Presenters profile

Dr. Ndukwe Agbai Dick is currently a Commonwealth Rutherford Fellow at the University of Nottingham. His research is focused on developing, expanding, and applying mathematical models implemented through GAMS for evidence-based policymaking in the agricultural and bioenergy (biofuels) sectors, and is being sponsored by Commonwealth Scholarship Commission in the UK, via the Rutherford Fund. One of his papers: the Nigerian Energy-Food Model (NEFM) has been published in the world's leading renewable energy journal – Renewable and Sustainable Energy Reviews. He has been endorsed this October as one the 'Exceptional Talents' in the UK by the British Academy and the UK Government.

Research on the Poverty Reduction Effect of Agricultural Infrastructure since the New Century: Evidence from China

Jiquan Peng[A] and Xiaodi Qin[B]

[A] *Jiangxi University of Finance and Economics, School of Economics, Jiangxi, China*

[B] *Zhongnan University of Economics and Law, School of Business Administration, Hubei, China*

Abstract

This paper uses spatial autoregressive model (SAR) and spatial error model (SEM) to analyse the impact of China's agricultural infrastructure on poverty reduction since the new century, based on provincial-level panel data from 2001 to 2017. It is found that both agricultural transportation infrastructure and agricultural production infrastructure have a significant negative impact on poverty. As for agricultural transportation infrastructure, highway density can significantly reduce the incidence of rural poverty by 1.424 units, river density can significantly reduce the incidence of rural poverty by 0.03 units, and railway density can significantly reduce the incidence of rural poverty by 0.0499 units. As for agricultural production infrastructure, the per capita installed capacity can significantly reduce the incidence of rural poverty by 0.122 units. The ability of soil erosion control can significantly reduce the incidence of rural poverty by 0.212 units. In addition, the control variables, such as the per capita planting area, the rural per capita education level, and the number of township health centres per capita, all have a significant negative impact on the incidence of rural poverty. Moreover, this study elucidates the mechanism of agricultural infrastructure poverty alleviation, indicating that agricultural infrastructure can reduce the incidence of rural poverty by reducing agricultural natural disasters, increasing various agricultural output values, and raising the income level of rural residents as well. Therefore, we can increase investment in agricultural transportation facilities and production facilities to reduce poverty.

Presenters profile

Dr. Jiquan Peng, is a lecturer in Jiangxi University of Finance and Economics, School of Economics. His research interest are rural economy and poverty of farmers. Peng Jiquan has been working on rural poverty and the livelihood of farmers. Peng Jiquan has published nearly 20 papers and hosted 8 projects on poverty topics.

M.A. Xiaodi Qin, is a lecturer in Zhongnan University of Economics and Law, School of Business Administration. His research interest are the poverty of farmers. Xiaodi Qin has been working on rural poverty. Xiaodi Qin has published nearly 5 papers and hosted 3 projects on poverty topics.

List of Attendees

Name	Organisation
Ndukwe Agbai Dick	University of Nottingham
Lucy Anderton	LA.ONE economics & consulting
Lado Arabidze	Georgian Technical University
Mohua Banerjee	International Management Institute Kolkata
Gustavo Barboza	Harper Adams University
Karl Behrendt	Harper Adams University
David Bullock	University of Illinois
Carl Dillon	University of Kentucky
Andreas Gabriel	Bavarian State Research Center for Agriculture
Morteza Ghahremani	Massey University
Terry Griffin	Kansas State University
Iona Huang	Kasetsart University
Kirandeep Kaur	Planning Department Government of Rajasthan
Jakab Kauser	Szechenyi Egyetem/University of Gyor
Ian Kumwenda	Harper Adams University
Ping Li	Chinese Academy of Grassland Science
Jess Lowenberg-DeBoer	Harper Adams University
Abdulkareem Luga	Harper Adams University
Søren Marcus Pedersen	University of Copenhagen
Tyler Mark	University of Kentucky
Daniel May	Harper Adams University
Gabor Milics	University of Gyor, Mosonmagyarovar
Hairong Mu	Harper Adams University
Jurkėnaitė Nelė	Lithuanian Institute of Agrarian Economics
Kehinde Oluseyi Olagunju	Agri-food and Biosciences Institute
Zainab Oyetunde	Natural Resources Institute, University of Greenwich
Motunrayo Oyeyemi	Nigeria Strategy Support Program International Food Policy Research Institute
Stamatina Papadaki	University of West Attica
Dimitrios Paparas	Harper Adams University
Jiquan Peng	Jiangxi University of Finance and Economics
Montchai Pinitjitsamut	Kasetsart University
Brian Revell	Harper Adams University
Antonella Riani Meirelles	Harper Adams University
David Rose	University of Reading
Eleni Sardianou	Harokopio University
Eva Schröer-Merker	Harper Adams University
Jordan Shockley	University of Kentucky
Eric Siqueiros	Harper Adams University
Karin Späti	ETH Zürich
Ourania Tremma	Harper Adams University
Simon Walther	Weihenstephan-Triesdorf University of Applied Sciences
Debin Zhang	Huazhong Agricultural University