Studies in Agricultural Economics 124 (2022) 44-58 https://doi.org/10.7896/j.2305

Mathilde AUBRY*, Zouhour BEN HAMADI*, Roland CONDOR*, Nazik FADIL*and Christine FOURNES*

Exploring digitalisation in the agri-food sector and its paradoxes: Evidence from a comparative study with small French companies

This paper discusses the results of a study on the digitalisation of the agri-food sector in a French region characterised by small- and medium-sized farms. Our results, which rely on a survey comparing digital practices in the agri-food sector with other sectors, reveal a paradox. While digitalisation is mostly perceived as a panacea capable of increasing agricultural productivity while respecting the planet, it is not widespread in the agri-food sector and even less than in other sectors of the same size. At the same time, the perceived impact of digitalisation is also lower than in other sectors. To increase the digitalisation of this sector, two elements emerge from our results: both the implementation of a global digital transformation strategy and membership of a professional association are required. Here, we refer to a broad definition of digitalisation, which includes organisational and social aspects, and does not only address technological dimensions. Our study challenges the technocentric and productive vision of digitalisation. It suggests that farmers' institutional environments and policies need to take a more holistic view of digitalisation to provide increased sense and generate engagement.

Keywords: agri-food sector, digitalisation, empirical study, organisational impact, small business, farms.
JEL classification: Q16

* EM Normandie Business School, Métis Lab, 20 Quai Frissard, 76600 Le Havre, France. Corresponding author: rcondor@em-normandie.fr
Received: 25 May 2022; Revised: 6 July 2022; Accepted: 11 July 2022.

Introduction

Digitalisation in the agri-food sector takes place in a specific context that faces "major challenges to feed a growing world population in a sustainable way, whilst dealing with major crises such as climate change and resource depletion" (Klerkx and Rose, 2020, p 1). As such, digitalisation appears as a solution capable of maintaining high volumes of production and to limit the negative impact of intensive agriculture (Llewellyn, 2018). It could be a solution for many farmers who are forced to be productive and sustainable.

However, this perspective remains institutional, held by firms providing digitalised solutions, carried out by political actors, and by actors from the agricultural sphere. Little is known about the real impacts of digitalisation (including the negative impacts) and the real practices of farmers. Questioning the future of digitalisation in agri-food sector, Lajoie *et al.* (2020), for example, frame digitalisation through a neo-Malthusian and techno-progressive lens as the solution to future food insecurity. The digital agriculture future is also described as "one much like the present, 'tweaked' rather than substantively reformed" (Lajoie *et al.,* 2020). Risjwick *et al.* (2019) evoke different views on the pace of change and the level of disruptiveness regarding agriculture digitalisation. This is in line with the holistic definition of digitalisation offered by Gong and Ribière (2021, p 10): "a fundamental change process enabled by digital technologies that aims to bring radical improvement and innovation to an entity […] to create value for its stakeholders by strategically leveraging its key resources and capabilities." All these scholars have opened a debate about what agriculture digitalisation is today and what it should be.

Indeed, whatever the point of view and the vision of digital agriculture, many works have emerged in this field (Lajoie *et al.,* 2021), including smart farming (Eastwood *et al.,* 2019; Klerkx *et al.,* 2019; Newton *et al.,* 2020), Agriculture 4.0, or precision agriculture (Trivelli *et al.,* 2019; Santos Valle and Kienzle, 2020). They deal with the benefits, risks, and impacts of digitalisation, but there are few empirical academic articles on the realities of digitalisation in the agricultural sector. Furthermore, such empirical studies focus mainly on regions of the world where farms are intensive, such as Australia (Fleming *et al.,* 2021; Newton *et al.,* 2020) or New Zealand (Risjwick *et al.,* 2019). These studies offer an interesting view of digital agriculture, but it is not representative of digitalisation all over the world. In addition, this paper answers in part to a key question asked by Ehlers *et al.* (2021, p 11) "whether farms, interest groups and government are willing and able to cope with the ramifications of a more encompassing digitalisation of agricultural policy. This would depend on the capabilities and the willingness of government, farms and the other actors involved to use digital technologies". The focus here is mainly on farms' digitalisation; in this way, it completes the work of Ehlers *et al.* (2021).

The aim of this paper is to explore the reality of digitalisation in a traditional agricultural territory – the Normandy – a French region characterised by farms of an average size (around 165 acres) and well known for their production of milk, beef, cider, or flax. We also compare the situation of the agri-food sector there to other sectors. In doing so, we complement existing studies, which often focus on large farms, and which do not provide a correct assessment of the digitization across the entire agri-food sector and neglect any comparison with the global economy. Through the regional lens of digital practices in Normandy, the article proposes an inventory of the digitalisation of the agricultural sector by addressing the following question: What is the reality of digitalisation and its perceived impacts in the agri-food sector compared with other sectors?

We relied on a survey about digital practices in Norman entities. We obtained 2,046 completed questionnaires, including 222 in the agri-food sector. The questions focused on the use of digital tools and perceived impacts, and more general questions about the characteristics of managers and their digital strategies were posed. To analyse the resulting database, we adopted an exploratory approach based on descriptive statistics and data visualisation. We focused our attention on companies with less than 10 employees, which represent the majority of the agricultural sector in Normandy.

Our results show that farmers are weakly digitalised and use digital tools at a level below other sectors of the same size. We also show that farmers are not interested in using digital tools because of a lack of vision about the interests of the digitalisation agenda in general. This point suggests that the digital discourse of institutional actors must not be too technical and must rather provide sense, generate engagement, and present a holistic view of digitalisation.

Our contribution is threefold. First, while the literature mainly focuses on digitalisation in terms of production, our work adopts a more holistic view by including the organisational aspects of digitalisation and considering a variety of digital management tools. Second, our research adds to previous works by providing an empirical demonstration of digital practices in the agri-food sector that have not been sufficiently explored (Schnebelin *et al.,* 2021). Thirdly, our study suggests various public policy options to spread digitalisation more widely within agriculture, based on this holistic vision.

After a synthetic presentation of the academic literature on digitalisation in the agricultural sector, we detail the emerging results of our database. These are then discussed, giving rise to managerial recommendations.

Literature review

Digitalisation can be defined either through a technocentric view or in a much more holistic way (see section 1 below). The issues and the positive or negative impacts of the digitalisation of the agricultural sector have also been studied from economic and societal perspectives. The organisational impacts need to be further investigated (see section 2 below).

Digital agriculture: What are we talking about?

Digital agriculture is often conceived from a technical perspective. As Ehlers *et al.* (2021) mention, "digitalisation is expected to transform the food and farming industry radically as, for example, it assists production with precision agriculture and trade through online platforms and traceability systems*."* Shepherd *et al.* (2018) show that digitalisation in agriculture is a long process that began in the late 1980s with GPS on tractors and yield mapping. Little by little, connected tools have been developed, which is now called precision agriculture (PA). Agriculture 4.0, a part of digitalisation, is composed of "different already operational or developing technologies such as robotics, nanotechnology, synthetic protein, cellular agriculture, gene editing technology, artificial intelligence, blockchain, and machine learning, which have pervasive effects on future agriculture and food systems and major transformation potential." It can dramatically "affect the way food is produced, processed, traded and consumed" (Klerlx and Rose, 2020). In sum, digital agriculture is "often defined in a farm-centric way, referring to the on-farm use of digital tools such as drones, sensors and GPS, i.e., automation and efficiency improvements" (Rijswick *et al.,* 2019).

However, in a general context that includes all the economic sectors, digitalisation is "much more than mere process redesign" (Liu *et al.,* 2011). It is a context for strategy change (Warner and Wäger, 2018) that "involves companies, business models, processes, relationships, products, etc." (Schallmo *et al.,* 2017). In other words, the digital transformation is not just a renewal of tools, but a renewal of the organisation, as new digital tools impact the way farmers work.

According to Rijswick *et al*. (2019), "digitalisation is often used to describe the socio technical processes surrounding the use of digital technologies that impact on social and institutional context that require and increasingly rely on digital technologies." Reis *et al.* (2018) categorise the definition of digital transformation into the following three distinct elements:

- Technological (use of new digital technologies such as social media, mobile, analytics or embedded devices)
- Organisational (a change of organisational process or the creation of a new business model)
- Social (a phenomenon that is influencing all aspects of human life, e.g. enhancing customer experience)

Therefore, digitalisation in agriculture refers to a large spectrum of activities, including not only the use of new technologies but also a reflection and an implementation of organisational changes on the farm. Digitalisation also refers to the generation of data, the creation of business opportunities from those data, and how the data will be used at all stages of the agri-food value chain (Bucci *et al.,* 2018), such as farm production, the processing industry, packaging, sales, and marketing, logistics and distribution, and consumers (Ramundo *et al.,* 2016). The common definition of digitalisation in agriculture lies somewhere in between and consists of being more connected, of using modern technologies such as drones and sensors to collect more data, and of sharing these data for better decision making. In fact, digitalisation impacts not only the organisation of the farm but also the relations between the farmer and his/her partners.

The challenges of agricultural digitalisation

In the literature, the challenges of digitalisation in the agricultural sector are mainly approached from an economic and societal perspective. From an economic point of view, digitalisation allows for gains in productivity and efficiency in the use of resources (Fleming *et al.,* 2021; Lajoie *et al.,* 2020; Risjwick *et al.,* 2019). Production quantity and quality are improved, and costs are optimised (Trivelli *et al.,* 2019). For example, the use of drones (or PA in general) allows for better crop and breeding monitoring and the early detection of pest problems and water shortages (Ayamga *et al.,* 2021). Similarly, agrobots offer labour and input savings and improved yields (Santos Valle and Kienzle, 2020). In general, this gain in productivity and yield due to digital technology allows agricultural enterprises to be more profitable and competitive due to improved adaptability and responsiveness (Trivelli *et al.,* 2019). Likewise, data-driven agriculture increases forecasting capacity, minimises risks associated with production, and creates more value (Lajoie *et al.,* 2020; Santos Valle and Kienzle, 2020). Digitalisation is perceived as a solution to food shortages: it allows farmers to address the problem of inefficiency through optimisation thanks to precision agricultural digital tools. They now have the ability to monitor, make visible (i.e. map), and predict environmental and agricultural systems. Rijswicks *et al.* (2019) mention the analytical possibilities and new sorts of decision support tools for farmers' advisors as well as new services. Digitalisation also allows a better treatment of risk and uncertainty: "For the World Bank, the risk and uncertainty, particularly within the context of a changing climate, means that conventional knowledge about agriculture is no longer adequate". Thus, "data driven agriculture is seen as helping mitigate the risks to farm productivity caused by a lack of predictability" (Lajoie *et al.,* 2020, p 8).

From a societal point of view, in the context of population growth and sustainability, digitalisation appears as a solution to increase production volumes while limiting the negative impacts of intensive agriculture (Llewellyn, 2018). Digital agriculture is thus part of the perspective of ecological intensification (Pretty, 2011) or "sustainable production intensification" (Santos Valle and Kienzle, 2020). This means improving livelihoods with quality nutrition, minimal inputs, and a low impact on soils and natural resources (Santos Valle and Kienzle, 2020). According to Shepherd *et al.* (2018), digitalisation also meets the needs of consumers who demand information regarding, for example, the quality of the products they eat, their origin, the use of pesticides, and the conditions of slaughter and treatment of animals. Beyond this "food sovereignty" and the requirements of this information age, digitalisation allows us to improve the working conditions of the farmer and to offer him/her decent work opportunities with an increase in technological skills. Agricultural activity is becoming more attractive, and the phenomenon of rural exodus is being mitigated (Santos Valle and Kienzle, 2020). Finally, for Bucci *et al.* (2018), another reason for introducing digitalisation in agriculture is to expand herds and improve productivity with livestock while preserving animal welfare.

This positive perception of connected agriculture as a solution to the food crisis is far from unanimously shared. According to Klerkx and Rose (2020) and Lajoie *et al.* (2020), the work associated with food security is techno-progressive, dominated by a Malthusian rationale that sees the rapidly growing population as the central problem and technology as the solution. However, limited access to food is rarely due to a lack of production; rather, it is often due to its unequal distribution. Agriculture 4.0 should not be seen as a panacea (Lajoie *et al.,* 2020). "The solution is not necessarily to produce more food but to distribute food more equitably" (Sen, 1982). The massification of agricultural production raises some questions about its social and ethical impacts. For example, the decrease in human involvement in favour of machines and artificial intelligence (Rijswick *et al.,* 2019) has changed the nature of rural employment and replaced small family farms with fewer, larger, and more commercial farms. Power within the value chain is being strengthened to the benefit of multinationals, including new entrants, such as Google (Birner *et al.,* 2021). Finally, digital technologies require an infrastructure, a level of skills, or, failing that, training and financial investments (Trivelli *et al.,* 2019) that go beyond the means of small- or medium-sized operations. Indeed, a sufficient market size is needed to invest in and make these investments profitable. In short, the unequal access to technologies can reinforce the social divide and inequalities (Birner *et al.,* 2021) at several levels, including rural/urban, small/large farms, female/male agriculture, and industrialised countries/developing countries.

Furthermore, in line with the thinking of Klerkx and Rose (2020) and Lajoie *et al.* (2020), we note a technocentric vision that focuses attention mainly on production tools and obscures administrative tools and support functions. Similarly, the impacts studied remain focused strictly on societal and economic dimensions. To our knowledge, no research has closely studied the organisational impacts that could also contribute to economic and social performance.

Data and methods

Sample and data collection

This research is based on data from a survey initiated by the Regional Council of Normandy and conducted as part of an observatory of digital transformations. This observatory is made up of various actors: chambers of commerce, agriculture and trades, a prefecture, a bank of territories, and academics (including one of the authors of this paper). The questionnaire was developed during several working meetings between May 2019 and February 2021. It was drawn from the field and reflects the concerns of the main stakeholders, including political actors in the region. It was administered to 2,046 companies (in agri-food, services, industry, construction, and trade) located in Normandy in February 2021. The quota sampling method was used. Thus, the sample retains the same characteristics as the population in terms of sectors of activity, distribution in the various departments of Normandy, and size of companies.

The objective of the questionnaire is to evaluate the level of digitalisation of companies from different sectors. It includes 39 questions on the presence of digital tools in the company, the impact of digital technology on the company, and digital strategies. This questionnaire is intended for several sectors of activity and does not refer to tools specific to a sector. It focuses on the presence and the perceived impact of various digital management tools (in communication, production, project management, finance, customer relationship management, etc.). This list emerged from the steering committees and is comprised of researchers, members of the Regional Council, and representatives of each sector (including the agri-food sector) during the construction of the questionnaire. Most of the questions are closed (i.e. respondents have to choose one answer from several choices), while others are semi-open, leaving the possibility for respondents to add an answer that is not among those proposed.

Appendix A provides a summary of the variables (from the questionnaire) used in this research.

In this study, we focus only on 1,159 entities with fewer than 10 employees. This choice is motivated by the desire to compare agri-food companies to companies of the same size in terms of number of employees from other sectors. Indeed, of the 222 agri-food entities in the sample, 213 have fewer than 10 employees.

Figure 1 and Figure 2 give details of the composition of the sample. Proportions represented are close to the sectoral classification of the National Institute of Statistics and Economic Studies (INSEE).

Agri-food is an important sector in the French economic fabric[1] and particularly in certain regions, including Normandy. According to the INSEE, in 2020, Normandy represented 4.3% of the Gross Domestic Product (GDP) of the French metropolitan area. This region is of great interest for our study because it comprises diverse agricultural activities: cow's milk cheese, butter, cream, cider products, textile flax, and leeks. It also ranks first in the number of horses. Moreover, its proximity to the sea allows the development of activities related to fishing and oyster farming.

The distribution of agricultural entities in our sample is presented in Figure 3.

Breeding activity alone is the most common, accounting for 42% of the sample, followed by crop production (20%). Associated crop and breeding activities represent 17% of our sample. 14% of the entities are support activities (e.g. agricultural contractors) for a third party in either breeding or crop production, and 8% have various activities such as fishing, forestry, and logging. All these activities constitute the core of the agri-food sector.

Methods

Our research is inductive and is based on exploratory data analysis; it is an approach based on "discovery, exploration and empirical detection of phenomena in the data" (Jebb *et al.,* 2017, p 265). Since the literature on the agricultural sector remains mostly conceptual, adopting an exploratory analysis responds to the need to discover phenomena previously unknown or very little addressed. According to Jebb *et al.* (2017), data mining promotes the detection of phenomena within organisations.

Although this methodology is not widely used in management science, it meets the objectives of our study. It is a matter of exploring a database without first defining the problem. "Researchers may conduct analyses that contain exploratory elements but then package them within a final confirmatory product. This mixing of exploratory behaviours within confirmatory settings allows the data to simultaneously generate and test the analytic plan, leading to hypothesising after the results are known and immunising scientific hypotheses from falsification" (Jebb *et al.,* 2017, p 266). According to Behrens (1997), exploratory data analysis answers the question "what is going on here?" and allows

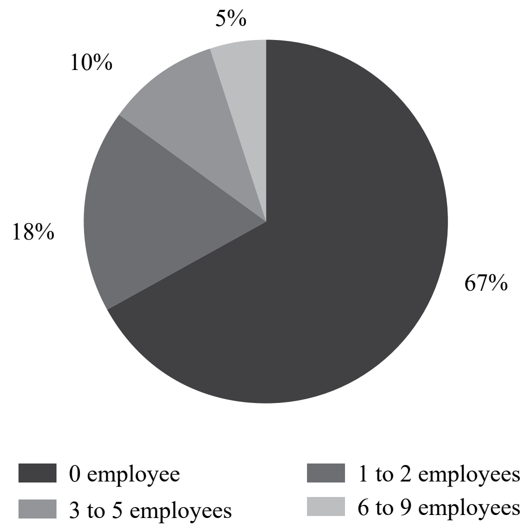

Figure 1: Distribution of the 1,159 companies by number of employees.
Source: Own composition

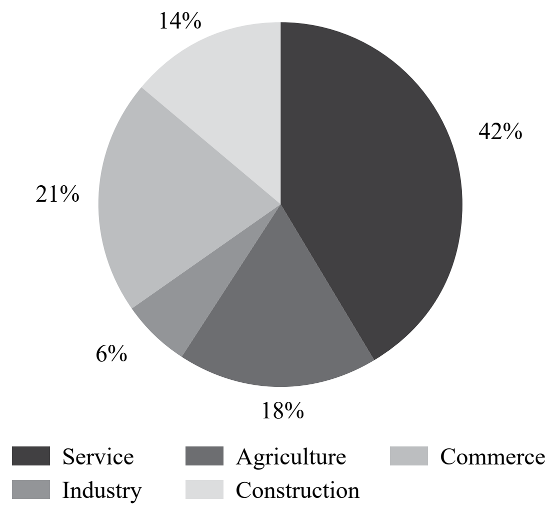

Figure 2: Distribution of the 1,159 companies by sector of activity.
Source: Own composition

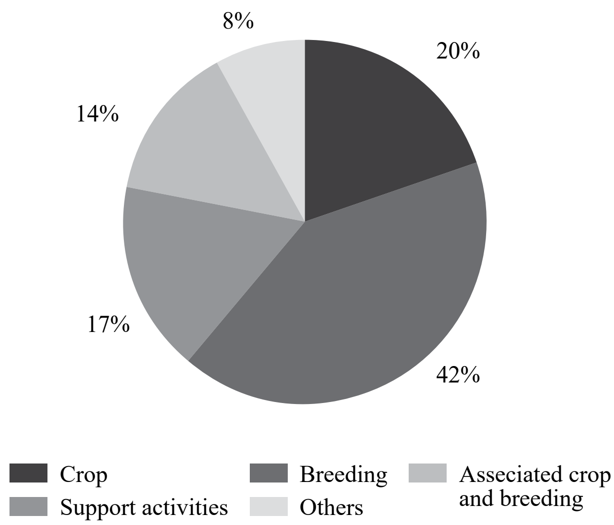

Figure 3: Distribution of 213 farm businesses by activity.
Source: Own composition

[1] It represents 1.7% of GDP, while it represents less than 1% of GDP in the United States and Germany and 1.4% of GDP for all OECD countries according to the latest available data from the World Bank (2020). (https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS)

for the construction of a rich mental model of the data. This is the core of our present research.

To meet the research objectives, quantitative empirical techniques and visualisation are central to exploratory data analysis in that the former maximise the value of the latter (Jebb *et al.,* 2017). We therefore use statistical tests that allow us to compare the agricultural sector and other sectors or to compare agricultural activities with each other. We use chi-squared tests and non-parametric Mann-Whitney and Kruskal-Wallis tests to determine whether independent groups come from the same population, which the null hypothesis confirms.

In a special issue on visualisation in the "Academy of Management Journal," the editors consider that "a picture is worth a thousand words" (Ertug *et al.,* 2018). It is therefore important to represent the data, be it with univariate graphs (such as histograms) or multivariate graphs (such as descriptive plots). Visualisation via these graphs not only allows the reader to understand the content of a study but also allows him/her to remember the same (Ertug *et al.,* 2018). Visualisation, which is common in management studies, helps reflect the quality of the data it represents. Illustrations reveal the characteristics as well as the relationships inherent and implicit in the data. The same authors believe that illustrations provide a comprehensive and quick visual to the reader. Visualisation, in the case of the present study, provides an optimal exploration of the available data.

Overall, to answer our question, we ground ourselves on the definition of digitalisation given by Gong and Ribière (2021, p 10), mentioned in the introduction and work on management digital tools.

Digitalisation in the agri-food sector

In presenting our results, first we focus on the presence of digital management tools in the agri-food sector to understand how agri-food entities are equipped and to compare their levels of equipment with companies in other sectors. Then, we continue this comparative work by focusing on the perceived impacts of digitalisation within the company. Indeed, as we have seen, digitalisation goes beyond the use of tools; it also includes the perception that digitising companies in general are interested in meeting global challenges.

Presence of tools in agri-food entities

Table 1 shows that, overall, agricultural entities are underequipped compared to other very small businesses. However, the differences between the sectors vary, depending on the tools used.

Chi-squared tests were performed to verify whether the differences between the agricultural sector and the other sectors were significant. It appears that belonging to the agricultural sector affects the presence of six different types of digital tools. Agricultural businesses are significantly less equipped than in other sectors regarding communication tools, financial management tools, online document storage and management tools, collaborative work tools, customer relationship management tools, and project management tools. The only tools for which the results are not significant are business management and steering tools, computer-aided design and/or production tools, and big data management tools. It should be noted that the latter are not used very much overall, as they are present in less than 10% of companies. Regarding computer-aided design and/or production tools, we are aware that the terms are not particularly well suited to this sector. This may have been a source of confusion for the respondents and may explain the low level of responses.

Table 2 shows the percentage of agricultural enterprises that employ various tools according to their activity. Businesses involved in crop production and support activities are the most equipped with digital tools, while businesses in breeding most often have the lowest rates. A notable exception is found in the case of design and/or assisted production tools: the rate of presence is higher in breeding farming than in other activities. This is probably due to the digitalisation of the dairy business (e.g. milking robots and the monitoring of animals through connected objects and smartphone applications).

Table 1: Share of enterprises equipped with different tools in the agri-food sector and in non-agri-food sectors.

Tools (percentage of companies for which tools are present)	Agri-food Sector	Non agri-food sectors	Total	Chi-squared
Communication tools	85.0%	93.2%	91.7%	15.607***
Financial management tools	27.2%	41.3%	38.7%	14.568***
Online document storage and management tools	18.8%	31.0%	28.7%	12.623***
Collaborative work tools	13.6%	20.0%	18.8%	4.610**
Management and steering tools for the company	10.3%	9.6%	9.7%	0.099
Customer relationship management tools	6.1%	15.4%	13.7%	12.786***
Computer-aided design and/or production	4.2%	7.5%	6.9%	2.911
Big data management tools	3.3%	5.8%	5.3%	2.194
Project management tools	1.4%	5.0%	4.3%	5.337**

***p < 1%, **p < 5%, *p < 10%
Source: Own calculations

Table 2: Share of enterprises equipped with digital tools in the different activities of the agricultural sector.

Tools (percentage of companies for which tools are present)	Crops	Breeding	Associated crop and breeding	Support activities	Other
Communication tools	92.9%	79.8%	83.3%	88.5%	90.0%
Financial management tools	33.3%	20.2%	25.0%	38.5%	35.0%
Online document storage and management tools	23.8%	13.5%	16.7%	23.1%	30.0%
Collaborative work tools	11.9%	12.4%	19.4%	15.4%	10.0%
Management and steering tools for the company	11.9%	11.2%	11.1%	7.7%	5.0%
Customer relationship management tools	7.1%	6.7%	2.8%	7.7%	5.0%
Big data management tools	4.8%	3.4%	2.8%	0.0%	5.0%
Computer-aided design and/or production	2.4%	6.7%	2.8%	0.0%	5.0%
Project management tools	0.0%	2.2%	0.0%	3.8%	0.0%

Source: Own calculations

Table 3: Perceived impacts of digitalisation.

Impact of digitalisation on: Very positive (2), positive (1), neutral (0), negative (-1), very negative (-2)	Average		Mann–Whitney test
	Agricultural sector	Non-agricultural sector	U
The circulation of information with partners	0.64	0.74	79,948*
Organisation and working methods	0.50	0.69	77,018***
Deadlines	0.50	0.62	78,091*
The visibility of your company	0.41	0.79	59,646***
Quality of service to customers	0.36	0.64	62,389***
Positioning in the sector of activity	0.36	0.63	63,955***
Quality of life at work	0.35	0.48	75,853**
Cost reduction	0.31	0.43	76 424*
The culture of the company	0.27	0.41	69 668***
Internal information monitoring	0.27	0.44	41 325***
The evolution of your strategy (business model)	0.25	0.44	63 606***
Human resources management	0.14	0.26	30 032**

***p < 1%, **p < 5%, *p < 10%.
Source: Own calculations

Perceived impacts of digital tools on agri-food entities

For each of the proposals listed in Table 3, below, respondents were asked whether they perceived a very positive (2), positive (1), negative (-1), very negative (-2), or neutral (0) impact. An average is again taken for each (see Appendix A).

The first column of Table 3, below, shows that respondents from the agricultural sector have a positive perception of the impacts of digitalisation, since the averages obtained are positive. However, they range from 0.14 to 0.64; therefore, they never exceed 1. More precisely, in the perceptions of our respondents, digitalisation has an impact on the flow of information with partners, organisation and work methods, and deadlines. In contrast, its effects are limited in the agricultural world on the company's culture, the monitoring of information internally, the evolution of its strategy (business model), and the management of human resources. Respondents in this field seem to view digital technology more as a means of interacting with the outside world (customers, suppliers, etc.) than as a means of managing internal flows. While this can be explained by the size of the companies for aspects related to human resources, it is surprising that digitalisation does not seem to be part of the strategy or the culture of the companies. Agricultural companies do not yet seem to be deeply concerned with digital technology.

In Table 3, the second column presents the scores of the perceived impacts of digitalisation in the other sectors and reveals that they are always higher than in the agricultural sector. We used the non-parametric Mann–Whitney test on independent samples to assess the differences in perception. The results are all significant; farmers perceive a lesser impact compared to companies in other sectors, regardless of the field. This means that beyond the low use of the tools, they hardly perceive their positive impacts and reveal a limited vision of digitalisation: dematerialisation without real transformation, or the transformation of the business model.

We constructed an "impact score" variable comprising the average of all perceived impacts, presented above, for each company. This impact score variable is presented in Figure 4.

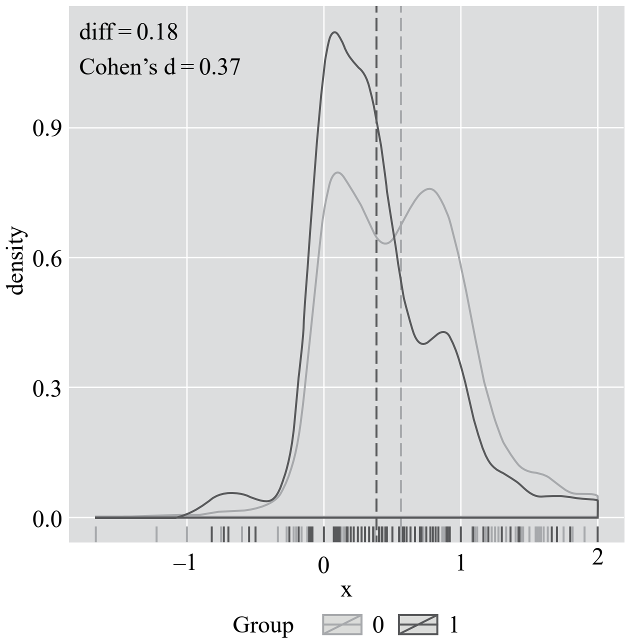

Figure 4: A group-means plot depicting impact score across sectors.
Note: The dotted lines represent group means.
Source: Own composition

This plot shows how the impact score differs by sector (agriculture in green-1 and the other sectors in red-0). From this plot, we observe that the estimated distributions of both agriculture and other sectors also do not appear to be approaching normality. This result is also confirmed by the Kolmogorov–Smirnov and Shapiro–Wilk normality tests. These tests are presented in Appendix B. In both cases, we observe an important asymmetry once again. Most of the firms in our sample, regardless of their sector, have scores between 0 and 1. Concerning the agricultural sector, the scores are mostly concentrated between 0 and 0.5. There are no scores lower than -1. Moreover, the agriculture distribution seems to have a smaller mean and variance. The average impact score is 0.39 for agricultural enterprises and 0.56 for other sectors. Cohen's d is again 0.37. The non-parametric Mann–Whitney test (presented in Appendix C) confirms that the two distributions are not equal *($p < 1\%$)*. Firms with low scores are relatively more numerous in the agricultural sector than in other sectors. In addition, firms with high scores are relatively less numerous in the agricultural sector than in other sectors.

The impact score averages according to the activities of the agricultural sector are presented, using boxplots, in Figure 5 below. The box plot whiskers range from no perceived impact to very positive.

The non-parametric Kruskal–Wallis test (presented in Appendix D) reveals that there is a significant difference between activities in terms of the perceived impact of digitalisation on agricultural businesses. The impacts of digitalisation are particularly and positively felt in support activities. Alternatively, the perceived impacts of digitalisation are weak in breeding and associated crop and breeding and may even be negative. Concerning the dispersion of the distribution, the size of the boxes shows us that it is particularly important for the support activities and the "other" categories, which include forestry and fishing activities. This can easily be explained by the diversity of the respondents in each of these categories. The dispersion is also particularly important in crop activity.

Relationship between usage score and impact score

Figure 6 shows a scatterplot linking the usage score and the perceived impact score. Here, we differentiate between agricultural businesses (shown in red-1) and businesses in other sectors (shown in blue-0). The usage score allows us to consider the frequency of use of the digital tools and not only their presence. Indeed, a company can have tools and not use them or use them infrequently. The usage score is obtained as follows: for each tool presented above, we assign a score of 0 if the tools are absent or never used, 0.25 when the tools are present but rarely used, 0.5 when they are used sometimes,

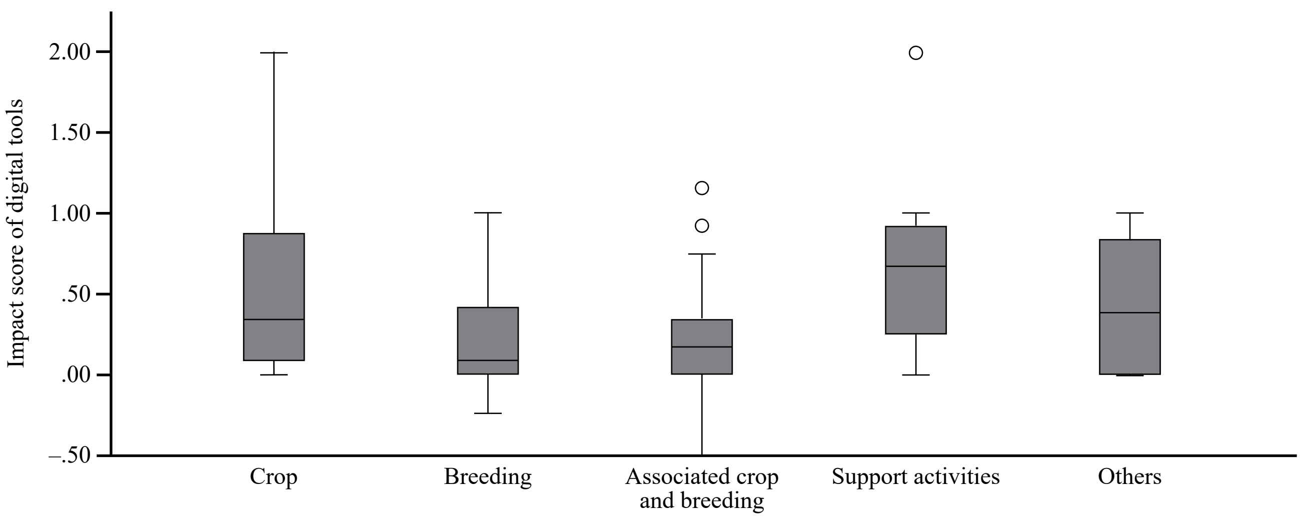

Figure 5: Distribution of perceived impacts by agricultural sector activities.
Source: Own composition

0.75 when they are used often, and 1 when they are used very often. To obtain an overall usage score, we average the nine tools presented in Table 1 and Table 2 above. Thus, for each respondent, we obtain a score ranging from 0 if none of the tools mentioned are used to 1 when all the tools are both present and used very often (see Appendix A). In this study, tool presence and frequency of use were highly correlated.

First, the graphic confirms that the usage score is lower in the agri-food sector than in the other sectors. The tools are not only less present, but also less frequently used. Second, the correlation coefficient for the agricultural sector between the two variables is 0.38 (*$p < 1\%$*). It is 0.44 (*$p < 1\%$*) for the other sectors. Therefore, both coefficients are positive and significant. Logically, the more frequently tools are present and used, the greater their perceived impact on the company. From this point of view, the agricultural sector is no exception. The lack of tools may explain why the perceived impact remains low in agriculture.

An attempt to understand the digital development of the agri-food sector

In this section, we seek to understand which variables may explain why some companies use digital tools more than others. Our results show that two variables are significant. The first is related to the way in which technologies are introduced into the company, and the second concerns the manager and his or her integration into professional networks.

In agricultural businesses, regardless of their activity, digital integration is mostly done on an *ad hoc* basis as opportunities arise (for 94.2% of businesses). In non-agricultural sectors, the integration of digital tools is done in 14% of businesses, according to a global and precise digital transformation plan (compared to 5.8% in the agricultural sector).

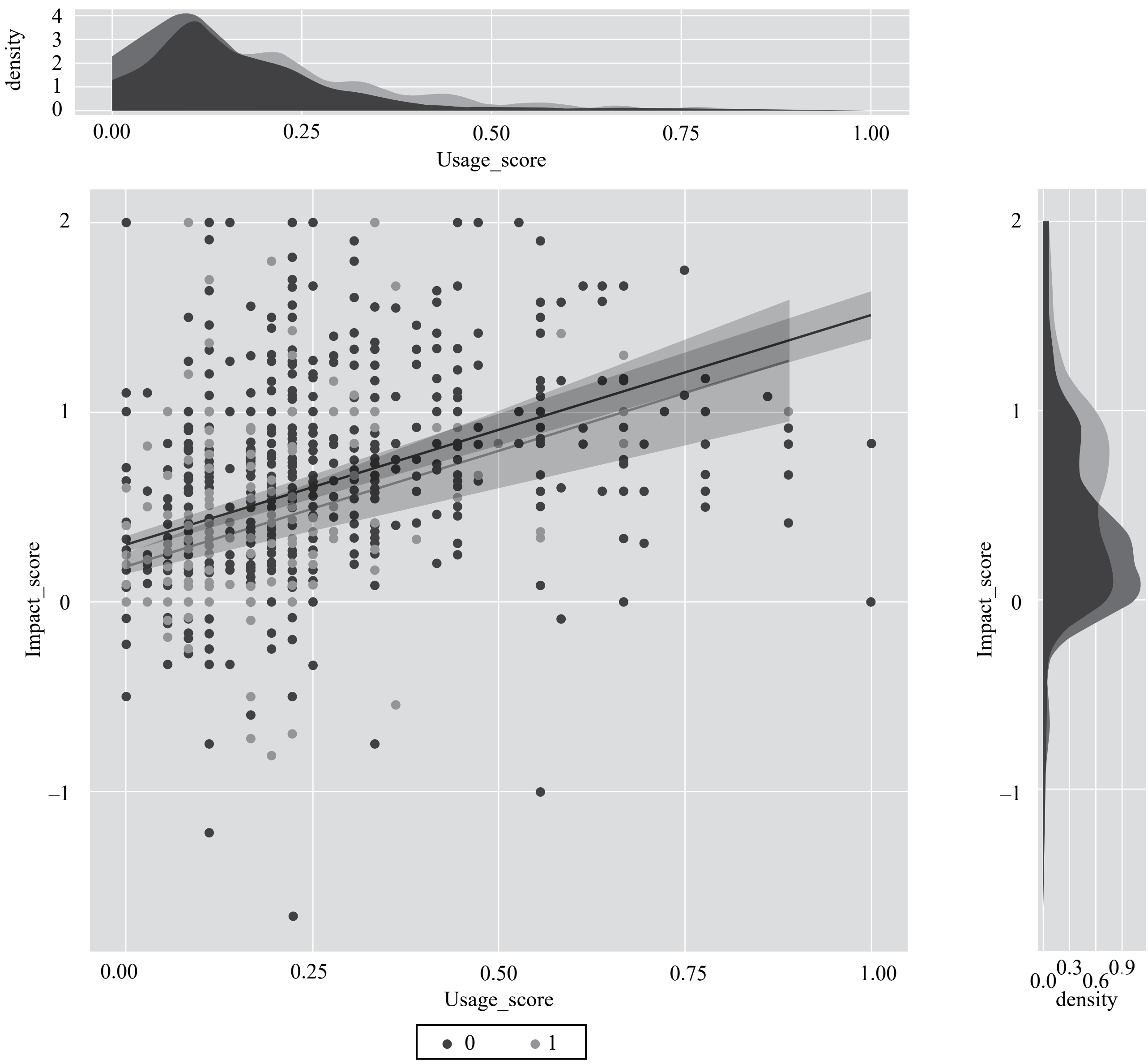

Figure 6: Point cloud (1-agri, 0-other sectors).

Source: Own composition

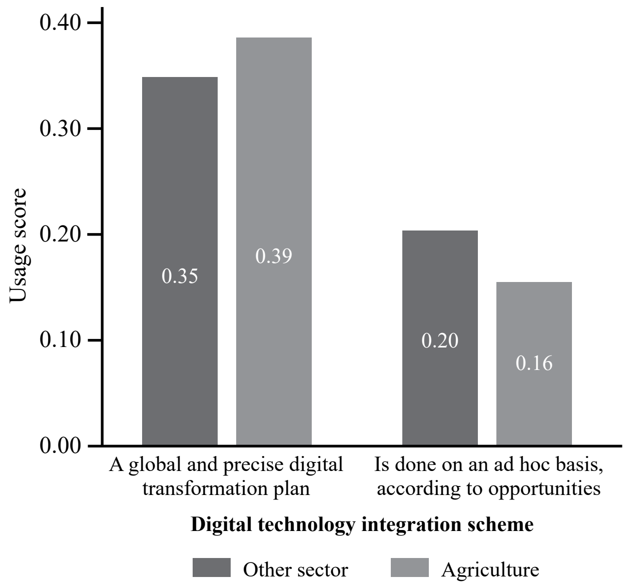

Figure 7: Distribution of the score for the use of digital tools according to the integration strategy of digital tools implemented and the initiator.

Source: Own composition

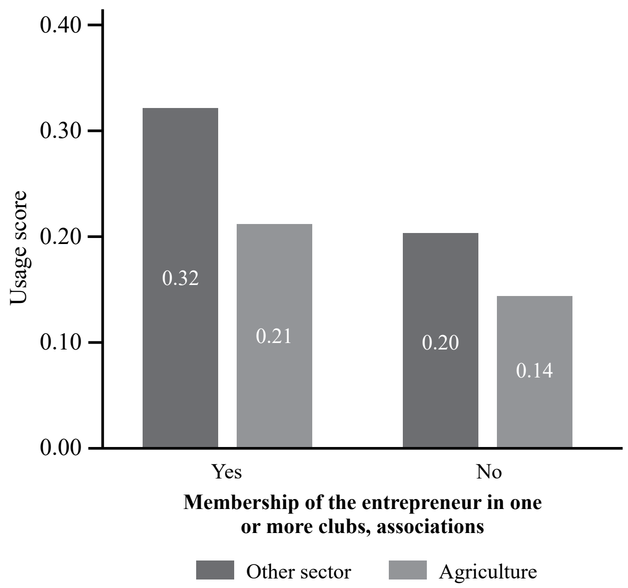

Figure 8: Distribution of the frequency of usage score according to the fat that the entrepreneur is a member of one or more professional clubs or associations in agriculture and in other sectors.

Source: Own composition

Table 4: Kruskal-Wallis tests on the usage score according to the integration strategy of digital tools.

Usage score	Agri		Others	
	H of Kruskal-Wallis	Sig.	H of Kruskal-Wallis	Sig.
Digital technology integration scheme	13.870	0.000	51.621	0.000

***p<1%, **p<5%,*p<10%

Source: Own composition

Table 5: Kruskal–Wallis tests on the usage score according to the profile of the manager.

Usage score	Agri		Others	
	H of Kruskal-Wallis	Sig.	H of Kruskal-Wallis	Sig.
Membership (Yes/No)	5.75**	0.015	28.275***	0.000

***p<1%, **p<5%,*p<10%

Source: Own composition

According to the graph presented in Figure 7, which represents the role of the integration strategy of digital tools on the score of their use, we observe that the score for the use of digital tools is significantly higher when the integration of digital tools is done according to a global and precise digital transformation plan. This result is particularly salient for the agricultural sector. The usage score is statistically higher than in other sectors when a global and precise digital transformation plan exists (0.39 for agricultural companies and 0.35 for others), whereas it is lower when this is not the case (0.16 for agricultural companies and 0.20 for others).

Table 4, below, presenting the results of the non-parametric Kruskal–Wallis tests, reveals that the digital technology integration scheme intervenes in the score of the use of digital tools for all sectors, including agriculture.

Unambiguously, the fact that the manager belongs to a professional club or association encourages the use of digital tools in the company: the usage score when the manager is a member of a club or an association is 0.21 and 0.32, respectively, for agricultural companies and others. It is only 0.14 (agriculture) and 0.20 (others) when the manager is not a member of a club or association, as shown in Figure 8.

The results of the non-parametric Kruskal–Wallis tests presented in Table 5 show that the differences are significant for all sectors.

These results are interesting because they suggest that farmers will have a greater propensity to adopt digital innovations if innovations are part of a global digital strategy transformation and if farmers are encouraged to use them by their network.

Discussion and policy implications

The agri-food sector is poorly digitalised compared to other sectors and a more holistic vision of digitalisation could lead this sector to an increased use of digital tools due to a better perception of its advantages (Section 1). The debate on the impact of digitalisation must address the organisational level (Section 2). Public policies could be reoriented with a focus on farmers and a holistic strategy that includes all stakeholders (Section 3).

The reality of digitalisation in the agri-food sector

Our study reveals several behaviours from farmers toward digitalisation. First, we highlight an underutilisation of digital business tools and, more generally, a weak perception of the positive impact of digitalisation on performance and strategy. Except for supporting organisations and some farms in crop production, rare are the farms that implement digitalisation, perceive its positive impact, and so understand the necessity to change. The comparison with other sectors (retail, industry, construction, etc.) clearly shows that agri-food seems to be less digitalised. This result is not explained by the size of the entities. Even though the questionnaire sent to farmers did not cover digital and connected tools specific to agriculture, such as GPS on tractors, milking tools, or various sensors, one question confirms that, at the production level, digitalisation is not advanced or perceived as essential. Indeed, our results show that farmers make little use of computer-aided production tools and even less use of big data management tools. The only digital tools broadly used by farmers are communication tools. This can be explained by several dimensions, including the small size of the farms surveyed, the characteristics of the farms, or the discourse of agricultural political institutions, which is more technical-oriented than business-oriented.

Second, we suggest that the farmers' institutional environment should have a more holistic view of digitalisation. Indeed, the dominant vision of agriculture digitalisation is technocentric and production-oriented (Lajoie, 2020). Digitalisation in agriculture is mainly defined as the use of digital tools such as captors and sensors and as the collection of data to better monitor agricultural production. Digitalisation consists of much more than its data-driven, technocentric view; it affects the entire value chain (Bucci *et al.,* 2018; Schallmo *et al.,* 2017; Sibona *et al.,* 2020). Once again, farmers have lagged behind and made little use of digital tools for support functions, while successful digitalisation is based on the interoperability of all digital tools, from production and commercialisation to support functions. Our point of view is that a holistic view that integrates a techno-productive and business perspective should provide more sense and increased engagement from farmers in terms of digitalisation.

Opening digitalisation issues to the organisational level

Even if the literature is not unanimous on the positive effects of digitalisation in the agricultural world, there is consensus on its ability to foster greater sustainable production and thus feed more people while optimising inputs (Fleming *et al.,* 2021; Lajoie *et al.,* 2020; Risjwick *et al.,* 2019). Previous academic papers exposed in the literature review have focused on the impacts of digitalisation on the production itself: growth of production, treatment of uncertainty, and sustainability. They have scarcely dealt with organisational impacts, with a few exceptions, which we present below.

Overall, our exploratory study notes a positive but weak perception of this organisational impact. This confirms some conclusions from the literature regarding the optimization of costs and deadlines and the increase of competitiveness (Trivelli *et al.,* 2019). They are more mitigated, however, when it comes to the improvement of the quality of working life (Santos Valle and Kienzle, 2020) and changes in strategy and business plan (Kolsh *et al.,* 2017). Other ignored by the literature, such as the internal and external flow of information, corporate culture and marginally human resources management, are added. The positive perception of the impact of digitalisation on these aspects of organisational performance remains common, regardless of the branch of agricultural activity (e.g. culture and/or livestock). However, it remains significantly lower compared to the perceptions of managers in other sectors, such as service, industry, and commerce. Thus, the best perceived impacts are in line with external relationships, such as the flow of information about stakeholders, delays, and the visibility of the company. Internal impacts are seen by the respondents as less important. For instance, the impact of digitalisation on the monitoring of internal flows of information, company culture, and strategy is not well perceived in the agri-food sector. Thus, our results give the impression that no link exists between the production and management functions of agricultural companies, while the data potentially made accessible by the production tools could otherwise be considered in decision-making and in improving internal management processes.

Policy implications

Our results suggest a reorientation of public policies. In Europe, the digitalisation of the agriculture sector mainly consists of supporting innovation by favouring transversal workgroups, including elected representatives of farmers, academics, start-ups and large farms or cooperatives. It also contemplates financing innovative projects to transform ideas into digital products or services that could be sold to the farmers. The objective of this public policy is to accelerate the digitalisation of the agricultural sector and build sustainable agriculture without altering the productivity of farms. This public policy is justified by the ecological transition, the need to feed a growing population, and the preservation of food sovereignty. However, farmers are not sufficiently targeted by policies and not sufficiently involved in local innovative projects.

Our research suggests that farmers should be placed at the centre of public policies. As we explained previously, most farmers do not see the interests of digitalisation. For some of them, digitalisation is comparable to modernisation after World War II: large firms in equipment and chemistry were the first beneficiary of the modernisation of the agricultural sector. Some farmers anticipate the same situation in the case of digitalisation: they experience the pressure of some start-ups and large farms trying to impose their solutions on the market. This research and innovation focus does not attract them in transversal working groups, even creating mistrust, particularly concerning the use of data (Gardezi and Stock, 2021; Wiseman *et al.,* 2019). Thus, they see participation in innovative projects more as a constraint than as an opportunity.

Farmers should be attracted by propositions that bring them immediate value added. As such, it would be interesting to balance the support between innovation and implementation, i.e. between innovation ecosystems and the farmers themselves. Farmers should be better supported through investing in digital solutions such as, for example, grants.

These grants could be given to specific farmers who have a global digital transformation strategy or/and those who are engaged in deeper sustainable transitions. Encouraging a holistic digital transformation avoids financing digital tools for production exclusively. The Food and Agriculture

Organisation (FAO, 2021), for example, explains that in some countries, investments in infrastructures, e-commerce or digital food supply chains, farmer training, and social media are as important as production-related digital tools[2]. However, all systems are connected; for example, a farmer may have an interest in investing in both a captor and software to manage his/her production. Encouraging farmers with a sustainable transition strategy is also preferable, as there is a need to accelerate the ecological transition of the agricultural sector. All these propositions allow us to target the attribution of the grants, control the public expenses, and cause a catch-up effect in terms of digitalisation of the agri-food sector compared to other sectors.

A factor that seems to be predominant in the process of digitalisation in agriculture lies in its affiliations to communities. The membership of an entrepreneur in one or more clubs or associations is the most key success factor of digitalisation. However, farmers do not seem to look sufficiently for support from their networks when implementing digital tools. In this sector, dependence on various stakeholders, especially regarding administrative issues, is strong. Thus, it is necessary that decisions, policies, and the promotion of agricultural digitalisation include all partners. This is the *sine qua non* condition for farmers to take full advantage of holistic digitalisation that integrates and links all their activities without any technological break.

This is consistent with Rijswick *et al.*'s (2019) conclusions that digitalisation in the agricultural sector "requires an organised reflection, anticipation of and responsiveness to the consequences of digitalisation in agriculture, for example including trust in technologies, data ownership and security, as well as inclusion of all relevant stakeholders to prevent growing inequality within the agricultural sector, e.g., the digital divide." Furthermore, in agricultural businesses, regardless of their activity, the integration of digital technology is mostly done on an *ad hoc* basis according to opportunities. This situation seems paradoxical because, in the agricultural sector, a holistic and precise digital integration plan is an even stronger lever on the score of tool usage than in other sectors. We thus confirm the need to implement a holistic strategy that considers the specificities of the sector and includes all stakeholders.

Conclusions and future research

The aim of this paper is to explore the reality of digitalisation in a traditional agricultural territory and to address the following questions: What is the extent of digitalisation in the agricultural sector compared with other sectors? What are its perceived impacts?

First, our results reveal a paradox. Indeed, while digitalisation is perceived as a panacea and encouraged by public authorities to increase agricultural productivity while respecting the planet, the reality is that the digitalised agricultural sector is underdeveloped and unequal compared to other sectors. This gap between actual and desired practices might originate from a production-oriented and technocentric vision. A key part of digitalisation is thereby neglected: digital management tools. An essential link is missing for the appropriate digitalisation of the sector: the digitalisation of non-productive functions. It is only under this condition that digital tools will be able to deliver on their promises, allow production, optimise all activities, and save resources.

Second, even if the perceived impacts of digitalisation are positive, their effects remain insignificant. Furthermore, the actors of the agricultural world seem to privilege the impacts on external relations and to neglect those on the internal organisation of firms. We suggest that public policies should develop a holistic view of digitalisation to better engage farmers in this transformation and to include all stakeholders. The technocentric view seems to be insufficient for promoting digitalisation in the agri-food sector, and the organisational issues must be addressed.

The literature on the digitalisation of the agricultural sector is recent and remains mainly theoretical. Our research provides a complementary empirical demonstration that considers organisational issues, going beyond broad economic and societal concerns. Thus, it leaves the techno-progressive framework that is focused on production tools and decried by certain authors, including Lajoie *et al.* (2020), and proceeds to examine management and administration tools. Admittedly, production is the dominant link in the agricultural value chain that would benefit from the positive effects of digitalisation. However, it is also true that all links in the value chain, including support functions, should be involved in digitalisation for improved optimisation of yields (Schallmo *et al.,* 2017) while ensuring sustainability in the management of all resources.

We identify three limitations to our study that may provide avenues for future research. First, our research focused on companies with less than 10 employees, the main characteristic of farms in our empirical study. However, it would be interesting to expand the sample to include larger companies. These are indeed more digitalised (Birner *et al.,* 2021; Rijswick *et al.,* 2021), and it would allow us to assess differences in practices. Second, the questionnaire used for this study focused on general tools without considering sector specificities. This allowed us to compare agriculture to other environments to put the digitalisation of the agricultural world into perspective and to compare practices. After highlighting the state of digitalisation in the sector and its limits, particularly in terms of organisational aspects, it would be interesting to analyse the agricultural sector in greater detail using a specific questionnaire. Thus, a future study should deepen the investigation into the digital practices of farmers, especially including the use of production tools (connected objects, sensors, etc.).

Finally, our study finds that the agricultural sector is less digitalised than other sectors as regards the tools used, which do not seem to be sufficiently anchored in all stages of the value chain. It would be interesting to explore this aspect further through a qualitative study to gain a better understanding of this situation. Another complementary issue can also be explored through a qualitative approach: What does digitalisation change in the farmer's daily life?

[2] See also a webinar organized by the FAO in 2021: https://www.youtube.com/watch?v=it13EvasgvY.

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Appendix

Appendix A: Operationalisation of Study Variables

Operationalisation of the variables characterising the tools		
The variables	**Nature**	**Measure**
Presence of communication tools (e.g. email, instant messaging) Presence Collaborative working tools (e.g. intranet, collaborative communication platform) Presence Project management tools *(Trello, Slack, Microsoft Teams...)* Presence Online document storage and management tools (cloud computing -cloud/drive, shared document management) Presence Customer Relationship Management (CRM) tools Presence of management and steering tools (ERP (Enterprise Resource Planning), PGI (Progiciel de Gestion Intégré), SAP,...) Presence Financial management tools *(e.g.: automated estimates and invoicing, online accounting, etc.)* Presence Big data analysis tools (data and big data) Presence Computer-aided design and/or production tools Presence of other tools	V. Dichotomous	The variables take the value of: 0: if the tool is not present 1: if the tool is present
Frequency of use of communication tools Frequency of use of collaborative working tools Frequency of use of Project Management Tools Frequency of use of online document storage and management tools Frequency of use of Customer Relationship Management tools Frequency of use of management and steering tools Frequency of use of Financial Management Tools Frequency of use of Big Data Analysis Tools Frequency of use of Computer Aided Design and/or Production Tools Frequency of use of other tools	V. Multinomial	A Likert scale ranging from 0 to 5: : DK (Don't know) 1: Never 2: Rarely 3: Sometimes 4: Often 5: Very often
Score for the use of digital tools	V. continuous (variable constructed by the authors)	Average frequency of use of all tools with a scale of 0 to 1: 0 : if the tools are not present or never used 0.25: if the tools are present but rarely used, 0.5 : if the tools are used sometimes 0.75 : if the tools are used often 1: if the tools are used very often
Operationalisation of the variables characterising the impacts		
Perceived impacts on : Organisation and working methods Human resources management Cost reduction The evolution of your strategy (business model) Reducing timeframes Quality of service to customers Internal information monitoring The circulation of information with partners (suppliers, administrations, etc.) Quality of life at work Corporate culture The visibility of your company Your positioning in the sector of activity	V. Multinomial	A scale of -2 to 2: -2 : Very negative -1 : Negative 0 : Neutral 1: Positive 2: Very positive
Impact score of digital tools	V. continuous (variable constructed by the authors)	Average perceived impact of digital tools within the company

Operationalisation of the variables related to the digital technology integration strategy		
The digital technology integration scheme	V.Binomial	Variable with a value of: 1: A global and precise digital transformation plan 2: piecemeal, as opportunities arise
Club/Association Membership	V.Binomial	Variable with a value of: 1 : Yes 2: No
The initiator of digital technology integration	V.Multinomial	Variable with a value of: 1: the leaders 2: Employees 3: an external company
Operationalisation of the contextual variables: description of the companies in the sample		
Number of employees	V.Multinomial	Variable with a value of: 1 : 0 employees 2 : Between 1 and 2 employees 3 : Between 3 and 5 employees 4 : Between 5 and 9 employees
Business sector	V.Multinomial	Variable with a value of: 1: Services 2: Industry 3: Construction 4: Agriculture 5: Trade
Agricultural business activity	V.Multinomial	1: Culture 2 : Breeding 3: Associated crop and breeding 4: Supporting companies 5 : Other (forestry, fishing, ...)

Source: Own composition

Appendix B: Normality Tests for the Usage Score and Impact Score Variables for the Agricultural and Non-Agricultural Sectors

Normality tests[a]

	Kolmogorov-Smirnov[b]			Shapiro-Wilk		
	Statistics	**Ddl**	**Sig.**	**Statistics**	**ddl**	**Sig.**
Impact_score	.088	917	.000	.971	917	.000
Usage score	.175	917	.000	.869	917	.000

[a] sector_agri = Other sectors
[b] Lilliefors meaning correction
Source: Own composition

Normality tests[a]

	Kolmogorov-Smirnov[b]			Shapiro-Wilk		
	Statistics	**Ddl**	**Sig.**	**Statistics**	**ddl**	**Sig.**
Impact_score	.144	194	.000	.927	194	.000
Usage score	.211	194	.000	.827	194	.000

[a] sector_agri = Agriculture
[b] Lilliefors meaning correction
Source: Own composition

Appendix C: Non-parametric Mann-Whitney tests for the variable impact score to compare two samples (firms in the agricultural sector and firms in other sectors)

Statistical tests[a]

	Impact_score
Mann-Whitney U	68,759.500
Wilcoxon's W	87,674.500
Z	-4.981
Sig. asymptotic (bilateral)	.000

[a] Grouping variable: sector_agri
Source: Own composition

Appendix D: Kruskal-Wallis Tests on Impact Score by Activity and Details of Distribution by Activity

Statistical tests[a,b]

	Impact_score
H of Kruskal-Wallis	13.491
Ddl	4
Sig. asymptotic	.009

[a] Kruskal Wallis test
[b] Grouping variable: NAF_code
Source: Own composition

	NAF_code	*N*	*Average rank:*
Impact_score	Crop	40	122.51
	Breeding	79	86.82
	Associated crop and breeding	32	83.81
	Support activities	28	106.09
	Others	15	100.20
	Total	194	

Source: Own composition

https://doi.org/10.7896/j.2286 Studies in Agricultural Economics 124 (2022) 59-65

Jehona SHKODRA*, Bedri DRAGUSHA, Prespa YMERI*, Lindita IBISHI* and Fjolla GASHI***

Analysis of determinants of efficiency in grape farming – the case of Kosovo

This study analyses the performance of vineyards in Kosovo in terms of their technical, allocative, and economic efficiency. It uses two methods to measure efficiency: Data Envelopment Analysis (DEA) and Tobit regression. The data comes from a survey of 165 wine producers through face-to-face interviews in three regions of Kosovo – Rahovec, Suharake and Prizren – between the years 2016 and 2018, each yielding the average of inputs, outputs and prices for the three years. In order to determine the key variables for grape growing efficiency, it was necessary to consider the combined effects of the interactions between inputs, as this has an impact on overall final production. The results show great potential for improving the efficiency of viticulture. The average technical efficiency (TE) is 0.68, the average allocative efficiency (AE) is 0.77 and the average economic efficiency (EE) is 0.52. In general, TE, AE and EE were influenced by the selected variables, suggesting that the selected variables played quite an important role in enabling farmers not to use too many inputs in the production of grapes and instead to use them in appropriate proportions. It also shows how grape growers can improve their productive efficiency by adopting certain practices and identifying the key factors in their system.

Keywords: farms, grapes, DEA, Tobit regression, efficiency, Kosovo.

JEL classification: Q12

* Department of Agricultural Economics, Faculty of Agriculture and Veterinary, University of Prishtina, 10000 Prishtina, Kosovo

** Department of Viticulture, Faculty of Agriculture and Veterinary, University of Prishtina, 10000 Prishtina, Kosovo. Corresponding author: bedri.dragusha@uni-pr.edu

Received: 19 April 2022; Revised: 28 May 2022; Accepted: 1 June 2022.

Introduction

Agriculture is one of the most important sectors of the Kosovar economy. It contributes about 13% of GDP and accounts for 5.6% of employment. It is the main source of income in rural areas, where an estimated 60% of the population lives (KAS, 2018).

Kosovo has a long history of grape cultivation and wine production. The total area of vineyards in Kosovo in 2019 was 3,367 hectares, of which 74% were planted with wine grapes and 26% with table grapes, and the total grape production in 2019 was estimated at 19,318 tonnes. The total number of vineyards in 2018 was 7,963, while the total number of farms was 4,571. The average area of vineyards under cultivation over the period 2010-2019 was 3,204 hectares. In 2014, the total consumption of table grapes per capita in Kosovo was 5.2 kg (MAFRD, 2015; 2018).

Unemployment is a major problem in Kosovo, where an estimated 25.7% of the population is unemployed (KAS, 2019). One solution to this problem is the development of agriculture in general and viticulture in particular. The correlation between the number of productive hectares and employment is conducive to alleviating the unemployment problem, as about 37 jobs are created for every 100 hectares added (MAFRD, 2015).

Grapes are grown in different zones of Kosovo, but the regions of Rahovec, Suhareka and Prizren are dominant in all respects, whether one considers area under cultivation, production, number of vintners or number of farmers. In Kosovo, more than 60 varieties are cultivated and grown for various purposes. These can be divided into varieties of wine grapes and varieties of table grapes. Productivity can be divided into two components: efficiency change and technical change. Efficiency change reflects the ability of a firm to achieve maximum output, while technical change reflects the movement of the efficiency frontier due to technological change.

Measuring the efficiency of enterprises is very important because it can help researchers, policy makers and producers to make decisions. Hitherto, there has been insufficient economic research on wine production in Kosovo. Therefore, this study conducts an empirical analysis of wine production performance in terms of technical efficiency (TE), allocative efficiency (AE) and economic efficiency (EE); it also analyses specific aspects of farm performance using measures of farm efficiency. Our findings will help define a framework for Kosovo viticulture, given its great importance in the context of domestic production, providing an in-depth analysis of the current efficiency conditions with a view to outlining operational proposals in the context of the new agricultural policy agenda.

Literature review

The role of agriculture in economic development is undeniable, hence the need to focus on enhancing the development of the agricultural sector. Research is therefore needed to determine the contribution of various factors to agricultural performance.

The value of data envelopment analysis (DEA) in scientific research lies in its ability to assess efficiency in comparison to an individual or to the performance of a decision-making unit in a well-defined group of interests. DEA was developed by Charnes *et al.* (1978) based on the studies of Farrell (1957) and has since evolved considerably due to various enhancements that have ultimately resulted in the method used in this study. The main advantage of DEA analysis is that it allows researchers to take a global approach to a farm, taking all inputs and outputs into account at the same time (Coelli, 1995), instead of considering them in terms of yield per unit of input. By looking at a farm's performance in terms of economic efficiency - both technical and allocative - and input-output, we can examine the individual components of profit maximisation.

For recent reviews of these studies, see Battese and Coelli (1995), who constitute the main empirical reference on the determinants of technical efficiency in agriculture. Townsend *et al.* (1998) studied productivity and farm size, using relationships between winegrowers to advocate for rural development, while Guesmi *et al.* (2012) compared the production efficiency values of organic and conventional grape farms in Catalonia. Sellers-Rubio *et al.* (2016) studied the efficiency of Italian and Spanish wineries over a nine-year period and found that the annual production of wineries in both countries declined over this period. Urso *et al.* (2018) analysed the efficiency of wine and vine producers in Italy and indicated that a reduction in grape prices led to an increase in the efficiency of wine-producing companies.

An analysis of agricultural production performance is an examination of efficiency, and efficiency is an indicator used in EU rural policy: highly efficient farms are considered more viable. The few exceptions include Gul (2005), who measured the efficiency and productivity of apple production in Antalya, Turkey; Plénet *et al.* (2009), who measured the efficiency of peach and nectarine production in France; and Ymeri *et al.* (2017), who studied the impact of farm size on the economic efficiency of poultry farms in Kosovo. Abate (2014) assessed the impact of agricultural cooperatives on the technical efficiency of smallholder farmers by comparing the average difference in technical efficiency between cooperative members and similar independent farmers. Bravo-Ureta *et al.* (2012), Kaleb and Workneh (2016), Kumbhakar (2009) and Mwalupaso *et al.* (2019), Kovacs and Szucs (2020) as well as Mitsopoulos *et al.* (2021) have also analysed the technical efficiency of agricultural production. To summarise, there are many studies on the efficiency of grapes, olives, citrus fruits, and apples, but this is the first study to analyse the efficiency of viticulture in Kosovo.

Data and method

In order to analyse and measure performance in viticulture, a formal and theory-based methodology was required, using appropriate data sets for comparison. This study was conducted in two steps: in the first step, a data envelopment analysis (DEA) and in the second step, a Tobit regression analysis was conducted. The use of this model can help to determine which area-specific or farm-related characteristics influence the differences in observed efficiencies. The results are therefore useful in building up a useful body of knowledge for private and public actors to guide possible reforms of EU interventions in the sector.

Measuring the efficiency of agricultural production is of particular importance, as it is an important source of information for decision-making as well as for the formulation of appropriate agricultural policies. Inefficient production results from the inefficient use of scarce resources (Dessale, 2019). To measure efficiency, a non-parametric approach was adopted using the DEA technique developed by Charnes, *et al.* (1978), Bournaris *et al.* (2019), Cook and Seiford (2009) and Zhou (2018). DEAP (v2.1) software was used for the calculations of DEA (Coelli, 1996). DEA is a mathematical linear programming technique that uses a frontier approach where the frontier function is a 'best practice' technique against which the efficiency of producers within the sample can be measured. The model allows individual and multiple efficiency analyses to be conducted for more than one producer and permits many inputs and outputs to be analysed using different units of measurement.

The production technique explains an output or input perspective. EE can be decomposed into TE, which measures the ability of the farm to produce more output with the same inputs or to produce the same output with fewer inputs, and AE, which measures the minimisation of input costs as calculated by the quantity of inputs and their unit prices. The combination of these two measures gives EE.

In DEA, "0" and "1" are used to represent efficiency values, with "1" corresponding to full efficiency. The choice of economic scale depends on the characteristics of production. When production is influenced by external factors, the variable returns to scale (VRS) assumption applies, and when enterprises operate at optimal size, the constant returns to scale (CRS) assumption is preferred. In the case of grape growing, it cannot be assumed that all growers operate at optimal scale, as grapes are very sensitive to external factors such as climatic and demographic influences, diseases, pests, and the ability of growers to carry out all necessary operations in the right way and at the right time.

Consequently, a DEA model of VRS was applied, where the technical input-based efficiency for each farm was obtained by solving a linear equation assuming VRS:

$$\begin{aligned} & minimize_{\beta_i\lambda}\ \beta i \\ & \quad -y_i + Y\lambda \geq 0 \\ & \quad \beta X_i - X\lambda \geq 0 \\ & \quad M1\lambda = 1 \\ & \quad \gamma \geq 0 \\ & \quad \beta_i \in (0, 1) \end{aligned} \tag{1}$$

where:
βi is a scalar that also measures the technical efficiency for farm i; X and Y are matrices of the inputs and outputs of all farms in the observation M; $Y\lambda$ and $X\lambda$ are the efficient projections on the frontier, and $M1\lambda = 1$ is a constraint for measuring VRS.

The values of technical efficiency obtained under VRS and CRS were used to obtain a measure of scale efficiency:

$$SE = \frac{\beta_{CRS}}{\beta_{VRS}} \tag{2}$$

Moreover, the determination of economic efficiency began with the solution of the cost minimisation problem:

$$\begin{aligned} & minimize_{\lambda X_i}\ \upsilon_i x_i^* \\ & \quad - y_i + Y\lambda \geq 0 \\ & \quad x_i^* - X\lambda \geq 0 \\ & \quad M1\lambda = 1 \\ & \quad \gamma \geq 0 \end{aligned} \tag{3}$$

where: υ_i is a vector of input prices; x_i^* is a cost-minimising vector of input quantities, given the prices υ_i and the output level Yi; and $M1\lambda = 1$ is a constraint on VRS.

The economic efficiency calculation was:

$$EE = \frac{v_i x_i^*}{v_i x_i} \tag{4}$$

The allocative efficiency calculation was:

$$AE = \frac{EE_i}{\beta_i} \tag{5}$$

Tobit regression was used for the regression analysis (Amemiya, 1974). The Tobit model evaluates the relationship between x_i (a vector of independent variables) and y_i (a non-negative dependent variable). z_i is an error term.

The model can be written as:

$$y_i = \begin{Bmatrix} y_i \ if \ y_i < 1 \\ 1 \ \ if \ y_i \geq 1 \end{Bmatrix} \tag{6}$$

$$y_i = \delta_0 + \delta x_i + z_i \tag{7}$$

where:

$z_i \sim M(0, \sigma^2), \quad i = 1, 2$

Data were obtained from interviews with farmers and represented farm characteristics, including inputs, prices, and production characteristics. The sample consisted of 165 grape farms in three regions of Kosovo: Rahovec, Suharake and Prizren. The study used average production data for the years 2016-2018.

Variables and hypotheses

Variables were divided into two groups: DEA variables and farm variables. DEA variables were divided into three categories: output variables, input variables and input prices, which are explained below.

Average revenue (AR) – represents the average revenue value received by a particular farm for all grape production during the period 2016-2018. This is our output variable.

The following variables were treated as our input variables:

Average quantity of fertiliser (AQF) – represents the average quantity of fertiliser applied during the period 2016-2018. This variable was measured in kilograms and normalised per hectare.

Average number of chemicals (ANCh) – indicates how often the plantation was treated with chemicals. The variable was expressed as the number of chemical treatments.

Average hired labour (AHL) – represents the average amount of labour hired, measured as the number of days of labour paid for per hectare.

Average cost for energy and services (ACES) – represents the energy and services paid for on the farm, normalised per hectare.

The following variables were representing our input prices:

Average price of fertilisers (APF) – represents the average price paid by farmers for one kilogram of fertiliser during the analysed period.

Average price for chemical treatment (APCh) – represents the price paid for chemical treatment per hectare.

Average price of labour (APL) – represents the average daily wage paid during the period 2016-2018.

Average price of service (APS) – represents the average price of services paid by farmers, normalised per hectare.

Farm variables were classified into four categories: resource endowment, production, input use, and the economic dimension, which are explained below.

Resource endowment was represented by four variables: farm area, farm irrigation and farm machinery value. *Total farm area (TFA)* was measured as the average utilised area of each farm included in the study during the period 2016-2018, expressed in hectares.

Hypothesis 1: TFA has a negative influence on farm efficiency.

Total irrigated area (TIA) was measured as a proportion of the total utilised area and expressed as a percentage (%). The impact on farm efficiency is explained by Haji and Andersson (2006), who show a positive impact on efficiency outcomes.

Hypothesis 2: TIA has a positive influence on farm efficiency.

Average machinery value (AMV), as reported by each farm. Grape production is labour-intensive, so many machines reduce efficiency because farmers will not be able to make the best use of all machines. Or conversely, advanced machinery increases efficiency. Asset value has a positive effect on efficiency (Haji and Andersson, 2006).

Hypothesis 3: AMV influences efficiency.

Production was represented by farm yield as average grape production on each farm (QY), expressed in kilogrammes and normalised per hectare. The expectation was that higher yield could lead to higher efficiency.

Hypothesis 4: QY has a positive influence on farm efficiency.

Input use was represented by the cost of materials and labour paid by each farmer. *Material cost (MC)* was the average cost paid by each farmer in 2016-2018 for the production materials used, normalised per hectare. *Labour cost (LC)* was the average cost paid for hired labour in 2016-2018.

Hypothesis 5: MC and LC have a negative influence on farm efficiency.

Economic dimension was represented by total production (TO), which was the average value of grape production in each farm. Carvahlo *et al.* (2008) use the value of total production and net income as indicators of the economic size of the farm and have found positive influences.

Hypothesis 6: TO has a positive influence on farm efficiency.

Results and discussion

Table 1 presents a description and summary of the variables used and the characteristics of each variable.

Results show that almost 97% of farms in Kosovo should focus on reducing input use and increasing the size of their farms. Unfortunately, the largest extent of change (59%) was an increase in the use of labour, energy consumption

Table 1: Description and summary statistics of the DEA variables (Average values for the period 2016-2018, n = 165).

Variable	Unit	Mean	Min	Max	Std. Dev.
DEA, efficiency variables					
Average revenue (AR)	€/ha	2,121.24	412.14	6,348.00	1,002.11
Average quantity of fertiliser used (AQF)	kg/ha	224.07	50.00	644.44	111. 36
Average number of chemical treatments (ANCh)	No.	4.17	2.00	8.00	0.7
Average hired labour (AHL)	wages/ha	16.64	0.36	63.93	8.77
Average cost for energy and services (ACES)	€/ha	271.25	117.98	1,704.03	139.58
Average price of fertilisers (APF)	€/kg	0.41	0.31	0.67	0.09
Average price of one chemical treatment (APCh)	€/ha	64.93	23.18	130.58	18.81
Average price of labour (APL)	€/wage	9.78	8.52	12.64	0.74
Average price of service (APS)	€/ha	43	26.57	169.43	12.9
Farm variables					
Resource endowment					
Total farm area (TFA)	ha	1.86	0.25	8	1.26
Total irrigated area (TIA)	%	64	0	97	0.33
Average machinery value (CMV)	€	5,264.47	0	45,309.69	4,773.29
Production					
Yield produced at the farm (QY)	kg/ha	12,245.53	3,500.00	28,200.00	3,478.25
Input use					
Cost of materials used (MC)	€/ha	691.15	289.42	1,995.18	196.28
Cost of labour used (LC)	€/ha	183.1	2.9	774	99.78
Economic dimension					
Total output (TO)	€	3,786.11	218.87	26,006.89	3,212.33

Source: Own calculations

Table 2: Frequency distribution and summary statistics for efficiency scores (average values for period 2016-2018, n = 165).

	Efficiency scores (VRS)			Scale efficiency		
Efficiency	**TE**	**AE**	**EE**	**CRS**	**VRS**	**SE**
≥ 0.90 ≤ 1.00	8	22	1	3	8	6
≥ 0.80 < 0.90	15	53	3	2	15	20
≥ 0.70 < 0.80	47	60	7	6	47	40
≥ 0.60 < 0.70	60	22	20	10	60	42
≥ 0.50 < 0.60	29	6	66	24	29	33
≥ 0.40 < 0.50	3	2	59	54	3	15
≥ 0.30 < 0.40	2	-	8	48	2	6
≥ 0.20 < 0.30	1	-	1	14	1	2
≥ 0.10 < 0.20	-	-	-	4	-	1
≥ 0 < 0.10	-	-	-	-	-	-
Mean	0.680	0.772	0.521	0.414	0.680	0.622
Min	0.348	0.417	0.211	0.103	0.348	0.126
Std. dev	0.116	0.101	0.115	0.131	0.116	0.132

Note: maximum value for the efficiency scores is 1.
Source: Own calculations

and services. Fertiliser use (36%) could also be a source of inefficiency. The result of the frequency distribution analysis is shown in Table 2, which provides detailed information on the efficiency parameters.

Table 2 shows that 65% of farms had TE values in the range 0.60-0.80; the lowest TE value was 0.35. TE could be increased by an average of 32% if farmers adjusted input use according to best practice. The average TE value was 0.68, the average AE value was 0.77, and the average EE value was 0.52. Complete TE was recorded on five farms, and complete EE was a feature of only one farm. Analysis of scale efficiency showed that 98% of the farms were operating at increasing scale (IRS), one farm was operating at decreasing scale (DRS) and two farms had full scale (SE).

The average value for AE was 0.77, the lowest value for AE was 0.42 and full AE was only achieved on one farm. This shows that a cost reduction of 33% is possible if farmers get better inputs at better prices. In addition, 68% of the farms operated within a AE range of 0.70 to 0.90. EE was calculated as a combination of TE and AE and the average value was 0.52, which means that there is a potential for efficiency improvement in the order of 0.48 if all farms become as efficient as the farms adopting best practice.

Moreover, Tobit regression analysis was used to determine the relationship between the DEA efficiency variables and the farm variables, where TE, AE and EE were dependent variables, and the farm characteristics were explanatory variables. The results are presented in Table 3.

The results presented in Table 3 show the differences between the coefficients TE, AE and EE resulting from the selected variables of the grape farms. Evidently, most of the selected variables have a significant influence on TE, AE, and EE. The results show that TFA has a significant negative influence on farm efficiency, which confirms hypothesis 1. In addition, TFA has an influence on TE, AE, and EE. TIA is significantly negatively associated with TE and EE, while AMV was not found to have a statistically significant relationship with farm efficiency.

The significant positive influences of operating efficiency (QY) and total output (TO) on operating efficiency were confirmed, but TO has an influence on TE, AE, and EE, while QY only contributes to the variation of AE and EE. It was hypothesised that MC and LC have a negative influence on operating efficiency and negative influences were expected. This hypothesis was only partially confirmed, as these two variables were found to have a negative influence on farm efficiency in general, but a positive influence was found for AE specifically.

In general, TE, AE and EE were found to be influenced by the selected variables. This shows that the selected variables are quite important and that farmers should not use too many inputs in the production of grapes and should use these inputs in appropriate proportions.

Conclusions

The aim of this study was to provide an empirical analysis of the performance of grape production in farms in Kosovo, assessed in terms of technical, allocative, and economic efficiency, and to relate production to efficiency scores. An analysis of efficiency using a DEA model allowed us to examine the determinants of efficiency of grape producers in Kosovo.

We conclude that most of the variables used in this study have a statistically significant impact on farm efficiency, increasing TE by 32%, AE by 23% and EE by 48%. The scale efficiency analysis showed that TE was on average 41% below CRS and 68% below VRS. In addition, 98% of the farms were operating under IRS, one farm was operating under DRS and two farms had full scale efficiency.

The results confirm that farm efficiency improves significantly when farmers manage to apply optimal combinations of inputs. They show how grape growers can improve their productive efficiency by adopting certain practices and identifying the key factors of their system. In this context,

Table 3: Tobit regression between the DEA efficiency variables and the farm variables (average values for the period 2016-2018, n = 165).

Variable	TE	AE	EE
Resource endowment			
Total farm area (TFA)	-0.0013**	-0.0033***	-0.0034***
Total irrigated area (TIA)	-0.0211**	0.0033	-0.0254*
Average machinery value (AMV)	2.20E-08	-2.32E-08	-1.28E-08
Production			
Yield produced at the farm (QY)	0.0001	0.0001***	0.0001***
Inputs use			
Cost of materials used (MC)	-0.0001***	0.0001*	-0.0001***
Cost of labour used (LC)	-0.0002**	0.0001*	-0.0001
Economic criterion			
Total output (TO)	2.12E-07***	2.08E-07***	3.50E-07***
Constant	0.8111***	0.5278***	0. 5146***
Log likelihood	200.1350	224.59312	215.2133
Pseudo R2	-0.2229	-0.2100	-0.2270
Sigma	0.1023	0.0547	0.0603

Note:* Statistical significance level at 10%, ** statistical significance level at 5%,*** statistical significance level at 1%.
Source: Own calculations

agricultural growth should only be supported if it is accompanied by measures to strengthen management capacities. Farmers need to focus on irrigating the entire area, using fewer tenants, using and paying for fewer inputs, and replacing older grape varieties with new ones to achieve higher value per hectare. Also, the new Rural Development Regulation should put more emphasis on specific measures for small and medium-sized farms that need a restructured production environment.

Conditions can be further improved by educating and training farmers in the proper use of inputs and for certain skilled activities. Strengthening extension capacities and cooperation are appropriate means to deliver these services. This requirement is also found in the EU agricultural policy, which sees investment in human capital and skills as crucial for the development of growth and employment opportunities in rural areas.

Based on the findings of the study, our suggestions for strategy and policy development can be put forward:

- Policy makers need to focus on increasing the production rate of productive farmers by providing them with easier access to financial and credit services. Productive farmers who have more working capital can operate on a larger scale and offer diversified products.
- Policy makers need to take effective measures to reduce input costs.
- Policy makers need to build communication platforms for farmers and other supply chain members to create long-term and closer relationships between them.

This paper has some limitations. The focus is only on Kosovo. Further cross-country research could be useful to confirm our findings in other areas, and more research needs to be done, including on our case (i.e. the role of price in influencing productivity), to provide more evidence on this topic.

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Marta MARSON*

Direct access to markets by farmers and the role of traders: insights from Kenyan and Tanzanian leafy vegetables markets

The research literature shows that agriculture has potential for development, job creation and structural change if agricultural value chains are considered in their entirety: from inputs, to farm, through processing, until marketing. This is particularly important in the case of Africa, where agriculture contributes in a major way to GDP and employment. However, this focus on value chains does not seem to have been accompanied by attention to the diversity of actors operating along value chains. Based on an extensive literature review on access to markets by farmers and on participatory research with farmers, traders, and sectoral stakeholders of leafy vegetables value chains in Kenya and Tanzania, this study argues that the role played by traders in local fresh produce markets in Africa is poorly understood and supported. It is argued that powerful narratives about the benefits of direct access to market by farmers, which are also present in academic literature, are sometimes overoptimistic, or interpreted beyond their scope and applied regardless of the specific features of actors and produce. The study shows that the leafy vegetables trade provides self-employment for many women, and that it has positive impacts on other groups, notably farmers.

Keywords: agribusiness, value chains, middlemen, Africa, farmgate, vegetables

JEL classification: Q13

*Department of Economics and Statistics, University of Turin and Turin Centre on Emerging Economies (OEET), Piazza Vincenzo Arbarello, 8, 10122 Torino, Italy. Corresponding author: marta.marson@unito.it

Received: 27 April 2022; Revised: 13 June 2022; Accepted: 15 June 2022.

Introduction

After decades of economic stagnation, African economies have more recently been growing rapidly. Even in per capita terms, GDP grew by more than 2% per year between 2000 and 2017 and natural resources and agriculture have contributed no less than a third of Africa's growth in recent years (OECD, 2013). Agriculture represents more than half of the employment in sub-Saharan Africa, providing jobs, income and food security, and its contribution to GDP in some countries, such as Ethiopia, is above 30%. This has paved the way to a new focus on agriculture as a productive sector, with the potential to drive development and growth, and not only as a residual sector providing cheap labour (Lewis, 1955) nor even as a default sector for the poor and a target sector for poverty reduction initiatives. The African Union Comprehensive Africa Agriculture Development Programme (CAADP) and the African Union declaration of Malabo (NEPAD, 2003; African Union, 2014) represent the African policy framework for agricultural transformation. Among other measures, they set a common target of 6% average annual agricultural growth and recorded the commitment by African governments to allocate 10% of national public budgets to the agriculture sector. Despite uneven results, this has caused agriculture to rank high on the development agenda.

Increasing agricultural productivity and promoting agro-based industrialisation is also considered a main way to address the global concerns raised by African demographic growth, with ten to twelve million youth entering the labour force every year (UNDP, 2015). Opportunities for job openings should be looked for throughout the value chain (from the farm via processing until marketing), as farming alone cannot offer enough jobs. In most rich, industrialised countries, farming employs only about 3-5% of the population, but processing and trading in farm products can employ far more than this share (Chipeta, 2013). Farming on its own is unlikely to generate large numbers of employment opportunities with the potential to transform the lives of rural people. This picture changes if the focus shifts from farm production to agri-food systems more broadly (Chipeta, 2013; Mellor and Malik, 2017). Consequently, emphasis has now shifted from crop production on its own to a broader notion of food value chains, whose development can increase agricultural productivity, add value, and, of course, improve nutrition. Entrepreneurship and job creation opportunities can be identified at each stage of the agricultural value chains and arise from the urbanisation dynamic in Africa, where towns and small towns play an important role. Tacoli and Agergaard (2017) highlight the role of processing and marketing centres for crops products from the surrounding area, as well as the role of the same centres as providers of agricultural inputs, services and technical assistance for the surrounding farmers, i.e. backward and forward linkages of agriculture, according to the Hirschman approach (1958). On the demand side there are opportunities both for export-oriented production and for import substituting processed and semi-processed products. Even the urban poor are buying processed food, which accounts for almost one third of their food budget in East and Southern Africa (Tschirley *et al.,* 2015). Moreover, the national urban middle classes have new consumption patterns: they increasingly demand non-grain food, like dairy, fish, meat, vegetables, fruit, tubers, and processed food (Reardon, 2015). Traders are important actors in food value chains.

Nonetheless, there is a lack of institutions and initiatives to promote entrepreneurship and agripreneurship by targeting food traders, and even the understanding of different markets and business models might be incomplete. Most of the available literature tends to represent traders as exploitative middlemen. A better understanding of local value chains is necessary to improve their efficiency and development which, in turn, can be expected to improve the welfare of all the actors involved, including farmers and consumers. Supporting business development is a top priority for the transformation of African agriculture and for agro-based industrialisation, but food traders and middlemen are seldom considered. The identification of target groups for agribusiness promotion is not straightforward (Sumberg *et al.,* 2014). Income-generating activities involving processing and marketing of agricultural products or street food vending usually have low start-up capital requirements, but also low profitability (Bryceson, 2002). Moreover, some do not have much potential for scaling up. Some low-return activities serve more as coping strategies than as a way out of poverty (Bryceson, 2002; Davis *et al.,* 2010; Sumberg *et al.,* 2014; AfDB, 2016). Also, Banerjee and Duflo (2012) refer to these actors as to default or reluctant entrepreneurs.

Based on original research carried out in Kenya and Tanzania about the value chains of leafy, mostly indigenous vegetables, this study shows the importance of identifying real actors who play a role in food value chains. More particularly, it is shown that traders connecting rural and urban areas, often referred to as middlemen, play a key role and that they are a neglected, sometimes stigmatised group. This activity was found to be beneficial both for farmers and for traders who come themselves from vulnerable groups and are mostly self-employed women.

These findings are discussed with reference to the market access literature (De Janvry *et al.,* 1991; Stringfellow *et al.,* 1997; Key *et al.,* 2000; Berdegué, 2001 and 2002; Schwentesius and Gómez, 2002; Kirsten and Sartorius, 2002; Osborne, 2005; Coulter, 2007; Hazell *et al.,* 2007; Barret, 2008; Hellin *et al.,* 2009; Kyeyamwa *et al.,* 2008; Shiferaw *et al.,* 2008; Markelova *et al.,* 2009; Bernard and Spielman, 2009; Markelova and Mwangi, 2010; Balaji, 2016; Sitko *et al.,* 2018; Nuthalapati *et al.,* 2020) which associates trade intermediaries buying at farmgate with market imperfections, rent positions, and inefficiency. The findings of this study show instead that direct access by farmers to markets is not a panacea and it is necessary to distinguish between different markets and value chains, as the market access narrative might sometimes be applied beyond its realisable scope.

The next section reviews the literature on market access for farm produce, with a particular focus on leafy vegetables. The third section introduces the methodology of the field work carried out in Kenya and Tanzania and the fourth presents its findings. The last section draws some conclusions and makes recommendations.

Literature review and research questions

The literature review is divided into three parts: the first covers studies which analyse the imperfections of markets for agricultural produce in developing countries and tend to identify direct access by farmers and farmers groups as the main solution capable of addressing them. This literature, while recognising some challenges of direct market access by farmers, tends nonetheless to criticise traders. The second part of the literature review covers studies that show instead the important role played by traders in some agricultural markets. The third part focuses on the markets and value chains for leafy vegetables in Africa in particular.

There is considerable literature about the need to provide farmers with market access, in most cases direct market access, thereby bypassing traders and middlemen (De Janvry *et al.,* 1991; Key *et al.,* 2000; Kirsten and Sartorius, 2002; Osborne, 2005; Barret, 2008; Barrett, 2008; Shiferaw *et al.,* 2008; Bernard and Spielman, 2009; Markelova *et al.,* 2009; Markelova and Mwangi, 2010; Balaji, 2016; Sitko *et al.,* 2018; Nuthalapati *et al.,* 2020). A main problem with commercial intermediaries seems to be the lack of competition at the farm gate which results in buyer power. Another problem frequently mentioned is the high number of subsequent intermediaries along the value chain, something which further erodes farmers' margins. Authors also point to imperfections that are pervasive in markets of the developing world (De Janvry *et al.,* 1991; Markelova *et al.,* 2009; Markelova and Mwangi, 2010), like market information asimmetries, scale related barriers, and access to credit.

These studies recognise that, when markets are spatially segmented and marketing costs are substantial and involve a significant fixed or sunk cost component, there is a minimum scale for arbitrage (i.e. simultaneously buying and selling something in different markets to take advantage of a price difference) to be efficient. This may create a natural oligopsony or monopsony (Barret, 2008; Osborne, 2005; Kirsten and Sartorius, 2002). However, this literature, instead of recognising the role of traders, points to their market power and concludes that direct access to markets by farmers is necessary to bypass middlemen. Some studies also recognise the challenges which can prevent individual farmers from succeeding in the market, but then conclude from this that collective farmers' action is necessary (De Janvry *et al.*, 1991; Markelova *et al.*, 2009; Markelova and Mwangi, 2010). Directly connecting smallholders' groups to markets is proposed as a solution to simplify long marketing chains by bypassing various marketing intermediaries and negotiate better terms of trade, as well as to reduce coordination costs (Barrett, 2008; Bernard and Spielman, 2009; Shiferaw *et al.,* 2008). Traders are also blamed because of the allocative inefficiencies of traditional markets resulting from multiple layers of intermediaries (Nuthalapati *et al.*, 2020; Key *et al.*, 2000) with more margins along the way (Sitko *et al.,* 2018) and even are accused of technical inefficiency, with wastage in the food chains (Balaji, 2016).

Such a "direct market access" narrative can be found in many development projects and initiatives, and it may even extend beyond purely scientific literature. However, a more careful look at the same literature shows that direct access to markets by farmers groups is not exempt from challenges. Literature points to transport and infrastructural constraints (Hazell *et al.,* 2007; Kyeyamwa *et al.*, 2008), gaps in technical and human capacity of farmers to handle the tasks, like specialised technical and marketing skills and knowledge (Stringfellow *et al.,* 1997) and to gaps in the leadership skills necessary to manage the groups involved (Schwentesius and Gómez, 2002). Some authors provide insights as to which situations and forms of farm produce may be appropriate for direct market access by farmers groups and which may make it more difficult. Farmers have seldom benefited from participation in farmer organisations for the direct marketing of undifferentiated commodities such as potatoes or wheat that are sold on the spot or at wholesale markets (Berdegué, 2001 and 2002). Perishable food products, like the ones considered in the present study, are also a special case. They imply high risk related to post-harvest losses; moreover, the required storage and transportation facilities are often beyond the reach of individual farmers, due to lack of funds and farmers may also lack the technical expertise to successfully engage in their marketing (Coulter, 2007; Hellin *et al.,* 2009). For perishable products there is also a need to coordinate the timing of supply with the pattern of demand and vertical coordination along the value chain is of vital importance in the marketing of such products (Poulton and Lyne, 2009). These arguments, however, are used to support the need for collective organisation by farmers (Coulter, 2007; Hellin *et al.*, 2009; Markelova *et al.*, 2009) rather than to recognise a role for traders.

Meanwhile, the literature defending traders is surprisingly scant. Sitko and Jayne (2014) argue that small-scale assemblers are both the most vilified and least understood actors in food value chains in sub-Saharan Africa. Drawing on data from Kenya, Zambia, Malawi, and Mozambique, they find that assembly markets for maize are highly competitive in terms of the number of traders operating and marketing margins. Farmers' market access conditions in remote areas are particularly improved by the operation of assembly traders, defined as the private traders who assemble grain at the village-level and in rural areas, as an intermediate step to reach urban markets. While smallholder farmers face important marketing challenges, according to the authors the brightest prospects for effectively addressing them require greater support for the development of assembly markets rather than supplanting them. Similarly, Abebe *et al.* (2016) propose important insights from Ethiopia, on the role that middlemen can play by linking farmers to final markets, where market failure commonly occurs. Their paper analyses the factors affecting farmers' decision to trade through middlemen and the impact of this choice on income. They find gross profit to be higher for farmers who operate without intermediation, thanks to their having access to better quality inputs and better contract specifications and receiving higher prices for their products. Nonetheless, most farmers continue to trade via middlemen, as it links them to traders and final markets. Direct trading with wholesalers seems to be beneficial for relatively better-resource endowed farmers.

Examples of the direct market access narratives can easily be found even in the sector of indigenous vegetables. Ngugi *et al.'s* (2007) analysis of the value chain of indigenous vegetables in Kenya, aims to ensure that farmers have direct access to supermarkets, allowing them to bypass middlemen and traders. The authors report on collective action taken by the farmers with the support of an international NGO. Farmers were organised into groups to sell their products directly to retailers at a higher price*, "bypassing middlemen and merchants altogether"* (Ngugi *et al.*, 2007 p.22). They provided a larger amount of produce and maintained a continuous supply and hence were preferred over other suppliers by supermarkets, i.e. high value markets. During low seasons when farmers did not have large quantities to offer, they pulled together the little they had and were still able to meet the orders from their supermarket clients. According to the author, the farmers made 55 per cent more margin per kilogram of indigenous vegetables sold, compared to farmers selling in the local markets. Similarly, Muhanji *et al.* (2011) describe a project in selected districts of Kenya and Tanzania to promote indigenous vegetables and their collective marketing by farmers. For this purpose, business support units were created, and the project promoted selling to formal high value outlets like supermarket by farmers directly. However, the report implicitly recognises the need for middlemen, because the project ended up using intermediaries, buying at farmgate or at collection centres, for informal, lower value, markets where margins are probably too low to cover the costs of direct access by farmers. Keller (2004) finds that almost three quarters of farmers around Arusha in Tanzania sell their vegetables at the farm gate. Most farm gate sales are to traders, but farmers can also sell directly to village consumers. According to the author such collecting middlemen can contribute to the efficiency of the marketing system, and they perform an important role in bridging a gap between isolated small-scale farmers and urban areas. According to Maro (2008) more than 80% of the farmers in his study around Arusha in Tanzania sold their leafy vegetables at the farm gate. Prices at farmgate are much lower than final markets prices. He finds that farmers receive less than 30% of final market price, while traders capture the remaining. Weinberger and Pichop (2009) find that the sum of retailers and wholesalers share of final price is 58%. Data, however, do not account for the respective costs borne by the actors, nor even for post-harvest losses. According to Maro (2008), farmers usually sell the whole plot regardless how much their plots yield, and this allows the trader to pay low prices. Moreover, more than half of the traders only pay farmers once he/she has sold the produce, and this is particularly common for wholesalers. The market fee was the major constraint experienced by 77% of farmers who brought their produce to the market. While the concentration of buyers at the farm gate is not assessed, the study finds that concentration in the markets is low, with both retailers and wholesalers pointing to "too many sellers" and "customers do not prefer leafy vegetables" as being the main constraints. Lotter (2014) confirms that producers generally sell leafy vegetables to wholesalers by plot and finds that the price varies with seasonality. Failure to sell in a timely manner is a main concern for vegetable traders, due to the perishability of the leaves. Retailers only purchase quantities which can be sold with minimum loss resulting from unsold quantities. In his survey in Dodoma, Arusha, Morogoro, and Iringa markets, Lotter finds that 62% of sellers store unsold produce and sell it the next day and calculated that the average end-of- business-day discount is around 13%. None of the sellers surveyed were registered as a business. The authors agree that leafy vegetable markets are very local (Maro, 2008), with more than 90% of the leafy vegetable supply in Dar es Salaam coming from production in the city itself (Putter *et al.,* 2007), and the average distance to market being 11.5 km (Lotter, 2014).

Table 1: Tools and sources of information and the research questions they help address.

	Degree of competition at farmgate	Prices	Value chain mapping and number of layers	Challenges faced by traders	Challenges faced by farmers
Market transect visits		■		■	
Production areas transect walking					■
Key informant interviews				■	■
Focus groups with farmers	■	■			■
Costs and revenues ex post recalling by famers		■	■		
Focus group with traders				■	
Individual interviews with wholesalers	■	■	■	■	

Source: Own composition

Fieldwork methodology

Fieldwork activities were carried out within the SASS research project, implemented by a consortium of Italian universities. The research was carried out in two countries, Kenya and Tanzania, and in four different areas characterised by different features in terms of remoteness from main market centres and the degree of development of the retail sector and urban demand. In one area, in-between Nairobi and Nakuru in Kenya, traditional greens are available in supermarkets for middle class urban consumers. In other areas, like Iringa and Dodoma in Tanzania supermarkets are hardly available and traditional vegetables are still perceived as poor people's food. This study presents the results of participatory research including market transect visits and farm transect visits with key informants, interviews of key informants, focus groups with farmers for value chain mapping, *ex post* recollection of costs and revenues by famers, individual interviews and focus groups with traders. The work is based on fieldwork in Nakuru County (Kenya), Arusha Urban and Rural and Meru Districts (Arusha Region of Tanzania), Dodoma Urban District (Dodoma region of Tanzania) and Iringa and Kilolo Districts (Iringa Region of Tanzania) conducted between August 2018 and November 2019.[1]

Based on the literature, the fieldwork tried to shed light on the possibly exploitative nature of the farmer/trader relationship, taking into account the effects of competition and buyer power, on the shares of final prices captured, and on the efficiency of the value chain managed by traders, in terms of the number of layers. The business model and problems experienced by traders and farmers respectively are also considered. Table 1 summarises the different tools and sources of information that have contributed to the study and the author's attempt to answer its research questions.

[1] Market transect visits: Gilgil and Naivasha (Nakuru County, Kenya), Kilombero, Tengeru and Samonge (Arusha), Machine Tatu, Kitonzini and Soko Kuu (Iringa), Saba Saba market Dodoma. Production areas transect walking: Dodoma, Iringa urban, Gilgil. Key informant interviews: market directors of Samonge and Kilombero martkets in Arusha, market association chairman of Kilombero market Arusha, Saba Saba market Dodoma, and Kitonzini market Iringa, chamber of commerce Arusha and Iringa, Arusha and Iringa Municipal Councils officers, urban and rural districts agricultural extension officers. Five value chain mapping focus groups with farmers: Gilgil (Kenya), UsaRiver, Oldonyowas, Lulanzi, Mazombe (Tanzania). *Ex post* recollection of costs and revenues by famers in the same five areas. Six Individual interviews with traders buying at the farm gate in Gilgil and one in Dodoma, plus a few individual interviews with retailers. One focus group with 6 traders in Iringa.

The focus of the study is on farm gate buyers, and in particular wholesalers who represent the overwhelming majority of farm gate buyers who met the researchers and were involved in the fieldwork. The traders who met the researchers are mostly women in the wholesale stage of the value chain, and exclusively women in retail, as men are seldom present in the sector. Transactions and relationships between farmers and traders are explored through focus groups with farmers and individual interviews and focus groups with traders, while insights on the retail stage of the value chain are obtained from interviews and focus groups with traders, and from market visits.

Results

The fieldwork provided insights into the degree of competition at the farm gate and in the wholesale markets, the potentially exploitative nature of the farmers/traders relationship, and their respective risks and margins. The business models and the efficiency of traders were also assessed and found to be largely driven by the perishability of the produce and by the risk of post-harvest losses and to require important skills. In this sense, the short shelf life and high perishability of the produce already described in the literature (Lotter, 2014) was found to be a main determinant of the features of the value chains.

Most farmers prefer farmgate buyers because this option reduces risk. Reaching markets is also relatively costly for their volumes of produce, a finding that is in line with earlier literature (Barret, 2008). Traders have multiple suppliers who in most cases sell also to other traders. Farmers in Arusha reported there are 3 to 10 different buyers visiting each of the areas, and traders in Iringa reported that their regular suppliers have up to three alternative traders to whom they also sell from time to time. Buyers in some cases use small trucks, but mostly they collect the produce from farms by motorcycle taxi (*boda-boda*), donkeys and carrying the vegetables on their heads. Collection in Arusha is sometimes performed by *boda-boda* drivers alone, while traders wait for the motorbike with the bags at the wholesale market, providing an example of noticeable coordination effort, which implies some management and logistical skill. From the tarmac road autorickshaws, collective minibuses and buses are used. Once the market is reached, traders must pay taxes and engage urban youth who carry the loads on their shoulders and, in bigger markets, sometimes operate as brokers for buyers.

Two slightly different patterns were found, which in both Iringa and Arusha roughly correspond respectively to the rural and peri-urban areas. In peri-urban areas traders book the produce in advance, with an unwritten contract with the farmers. Contact between the farmer and the selected trader is frequently via mobile phones, through which the traders coordinate their suppliers. Harvesting, sorting, binding, and packing are done by the buyer. Producers usually negotiate the price of the plot, without going into detail about the number of bags, kgs or bunches which will be harvested from it. However, this does not mean that the buyer bears the risk of crop failure or low yield, because the price is only negotiated at the time of harvesting, when the performance is already observable. Farmers are usually paid only an advance sum at harvesting time, while the final payment is done after the produce has been sold by the trader. This delayed payment supports findings by Maro (2008) and is justified by liquidity constraints experienced by traders. Delayed payment also allows the traders to renegotiate the price if they fail to sell. Failure to sell is something that farmers can't control, but traders explained that trust is usually there, and cheating would be easily discovered, particularly if repeated. Although farmers usually can choose alternative buyers, a kind of loyalty on the part of the farmers towards a preferred trader was found in peri-urban contexts, where the farmer is expected to offer vegetables at a better (i.e. lower) price to the reference trader than to other traders. At any time, the farmer can decide to sell to other traders who pass by the area to visit other farmers offering higher prices, but this affects mutual trust with the reference trader. Mutual trust in fact reflects the commitment by the farmer to sell to the trader and, on the part of the trader, the commitment to come at the right time for harvesting. If the trader does not come, farmers bear the risk of post-harvest losses, which is otherwise fully transferred to the trader.

In contrast, in rural districts traders just look for plots ready to be harvested. They do not book the plot in advance, and they pay the whole amount at harvesting. Another difference is that, while traders in the urban area are the ones who harvest, sort vegetables, and prepare bundles, farmers who are reached without any previous order and paid on the spot, can also be expected to perform these tasks. Farmers from rural areas also recognised their need for traders, but they did not refer to mutual trust and loyalty in the relationship with them. In these areas, buyers might change from time to time, they simply pass by and collect vegetables, paying on the spot. Lower confidence in traders might also be explained by fact that farmers situated far away from town only have a very rough idea of market prices and demand in town. This makes their capacity to assess the fairness of the deals with a trader lower, than that of peri-urban farmers who have better insights into markets. In any case, to make sure that the price proposed by the trader is fair, farmers reported that they get price information from the markets from relatives and friends through mobile phones.

Overall, it was found that there is some competition among farm gate buyers, meaning that no monopsony situation could be detected. Direct access by farmers to markets was found to be negligible, in line with previous literature (Keller, 2004; Maro, 2008). Farmers themselves reach out to markets to sell when farm gate buyers are not available, which might happen during the season when vegetables are widely available and their price becomes too low. Farmers can also sell in retail in their respective neighbourhoods but, despite being positively rated in terms of profitability, this trade accounts for a small share of the total due to the low volume demanded.

In line with Maro (2008) and Putter *et al.* (2007), it was found that transport is limited to nearby markets. Moreover, no aggregation or assembly markets for leafy vegetables were found (i.e. markets located close to production areas where the produce is aggregated to be sent to urban markets). Virtually no leafy vegetables are sent to other counties and regions, apart from Nairobi, which is supplied from Gilgil thanks to its proximity. Consequently, traders who buy indigenous vegetables at the farm gate, bring the produce straight to the wholesale market of the area where the produce will be consumed. This arrangement, without intermediate steps, is due to the perishability of leafy indigenous vegetables, which force traders to limit the number of links in the value chain, to ensure timely delivery. In this sense, the value chain studied is short and efficient, without the high number of intermediaries, or middlemen, that is sometimes blamed for jeopardising the efficiency of African markets (Nuthalapati *et al.*, 2020; Key *et al.*, 2000; Sitko *et al.*, 2018; Balaji, 2016).

Wholesale markets for leafy vegetables, in all the areas assessed, only work before sunrise and in the early morning. In most cases leafy vegetables do not enjoy a dedicated space in the open-air market. While all urban markets in Nairobi, Nakuru, Iringa, Dodoma, and Arusha sell indigenous leafy vegetables, wholesale is only carried out in few of them. However, in these markets (*Samunge* and *Tengeru* in Arusha and *Saba Saba* in Dodoma, *Gikomba, Marikiti, Muthurwa*, and *City Park* in Nairobi, but other can be found in the peri-urban areas) there is no permanently dedicated area for leafy vegetables wholesale. The areas used in the early morning for wholesale of leafy vegetables then become a retail market for various vegetables, and even for different items. In one case, in Iringa, leafy vegetables were found to be sold at wholesale just outside the formal market premises, along a steep slope and without any shed or pavement, to avoid paying market tax.[2]

Other vegetables which are less perishable and more often traded by men and they enjoy a dedicated space for wholesale in the market, so that wholesaling activities can continue throughout the day. This is the case for tomatoes and cabbages in *Kilombero* market in Arusha, where a dedicated shed is available. The same happens for fruit and exotic vegetables in *Machine Tatu* market in Iringa, and *Saba Saba* market in Dodoma.[3] The areas used for wholesale of leafy vegetables

[2] In Dodoma traders with the trader id card, an initiative of traders' regulation and formalisation by the government of President Magufuli, do not pay to sell in the market. In Arusha and Iringa instead, the card is only considered valid to sell outside markets' premises and registered traders still have to pay market taxes, per bag and per day.

[3] In Dodoma, the wholesale market for greens is *Saba Saba* market. Wholesale of green vegetables used to take place in *Majengo* market, before the market was upgraded and renovated in 2013. Greens' traders were relocated in a dedicated area in *Maisha Plus* market, but, due to the remoteness of this market, they do not use it and prefer the more busy and central *Saba Saba* market. In *Saba Saba* however, they do not have a dedicated space and, from 8 a.m. the area they used is occupied by second-hand shoes traders, so that they have to leave, with their left-over vegetables.

instead must be abandoned in the morning to leave room available for retailers.

In these markets, buyers are retailers, restaurants and organisations managing canteens. The people, mostly women, who sell at wholesale, are often referred to as farmers, since they come from the countryside and look like farmers. Some of them get the produce from their neighbourhood, some from relatives, and some produce a share themselves. They should nonetheless be considered traders, as they devote most of their working time to this trade. Wholesalers bring their baskets[4] and bags to the market before sunrise. Interviews with traders confirm that they harvest and buy at farmgate in the afternoon and travel to the markets in the night to reach there in the early morning, in line with findings by Lotter (2014). Some traders from the surroundings of Arusha and Nairobi, go to different markets in different days, following the weekly schedule of many open-air markets, or change markets depending on prices and demand. Most traders go to the market 3 or 4 times per week, implying that they devote the preceding day to procuring vegetables from the countryside, and that, overall, they devote most of their time to the business.

Most farmgate buyers are wholesalers, some are also retailers, some adopt a flexible business model changing from time to time. Some better off traders do not pass through the open-air markets, as they have direct relationships with their regular buyers, namely retailers, hotels, restaurants, private schools and, particularly in Kenya, even supermarkets. Regular outlets are better than spot markets because they reduce the risk of post-harvest losses which is a main issue for traders of leafy vegetables.

Seasonal oversupply and huge post-harvest losses are important for most leafy vegetables[5], in line with previous studies (Maro, 2008; Lotter, 2014). The chairman of the traders' association of a market in Iringa (Tanzania) regulates the wholesale trade of greens in that market, even though the women who sell the greens are not formal members of the association. He explained that he had to introduce a system of weekly shifts among women trading green vegetables, depending on the areas they come from. This was done after experiencing oversupply and a consequent fall in prices and conflicts among women traders. Based on these considerations, low prices faced by farmers at the farm gate are at least partially explained by seasonal oversupply and by huge post-harvest losses, rather than by high traders' margins. Post-harvest losses were estimated by traders in Iringa to be above 30% of the total value of vegetables.

Farmers' shares of the final price were found to be highly variable, but slightly higher than in previous literature (Maro, 2008; Weinberger and Pichop, 2009), and much higher when, to consider post-harvest losses, the farmer's share is recalculated with reference to the quantity that is sold by the trader, rather than with reference to the quantity she purchases. This increase in the farmers' share could be due to improved access to information on prevailing market prices on the part of farmers, or to reduced costs for traders thanks to the now popular *boda-boda*, which recently made a big difference in rural Africa accessibility generally, and in the study area as well.

Traders were found to lack any kind of collective organisation in all the locations covered by the study. They are not registered at local chambers of commerce, and they are not even members of traders' associations for open air markets. Nonetheless, market traders' associations can exert some power over small traders of vegetables as evidenced by the case of the chairman introducing the shift system in Iringa.

Most traders met in Tanzania, and all the traders in the focus group enthusiastically adhered to the initiative by President Magufuli for the regulation of informal traders.[6] While this recent initiative of traders' regulation and formalisation was seen as a way of raising fiscal revenues by observers, traders did nonetheless adhere enthusiastically, demonstrating their commitment and readiness to engage in support programmes. Traders attending the workshop in Iringa identified and ranked their priorities to improve their businesses.

A main priority for them is to find regular buyers to reduce the risk they bear. This does not necessarily refer to formal contracts but to agreements with institutions and businesses (like schools, restaurants, etc.) which can ensure reliable and regular outlets for their produce. While some traders have this kind of regular customer, other do not. Regular buyers and bulk buyers, due to the high competition among traders in urban markets, can easily find indigenous vegetables, so that that they can take advantage of perishability of the produce to get good prices and they do not need to engage in long term relationships and agreements with traders. A second priority mentioned is training in business management, as none of the traders met has ever been targeted by any training initiative, and they are not members of any association or chamber of commerce. Despite their key role in supplying urban markets and linking farmers to final customers, the potential of traders is not developed. Traders have already developed leadership and marketing skills and they have at least a basic understanding of institutions governing urban markets and corresponding taxes. They have also mastered basic calculations of costs and revenues. While the importance of these skills is sometimes disregarded by authors and experts promoting direct access to market by farmers groups (Stringfellow *et al.*, 1997; Schwentesius and Gómez, 2002), the traders who participated in the study were aware of it and eager to get more. The two priorities mentioned respectively refer to the notions of competition, confirming that traders bear high risk, and to the issue of efficiency and skills.

Although the profits reported by traders are reasonable by local standards, and regardless of the dimensions and success of the business, in most cases they do not see the vegetables business as something with the potential to transform their lives. Traders interviewed in depth showed a limited capacity to envision the future development of their businesses.

[4] While in Gilgil and Arusha big bags obtained from maize bags are used to transport leafy vegetables in Iringa and Dodoma region bags are seldom used to transport leafy vegetables and the traditional *tenga basket*, available in different dimensions is preferred. *Tengas* are flat, circular baskets, with very large hole between the strips. When compared to the maize bags, an advantage of *tenga* is that it allows air to flow better, but it is also more difficult to transport it with public means of transport available because of the big diameter.

[5] Quite surprisingly the lowest prices are not always registered towards the end of the main rain season. This is due to three reasons: most of indigenous vegetables production in the area is not rainfed, but watered; the strong rains of the main season can damage IV, which are very prone to rotting; the poor accessibility of markets and worsening conditions of rural roads during the main rain seasons also contribute to keep the price quite high.

[6] Ibidem 1.

Scaling up the vegetables trading in fact is very challenging, due to the lack of certain demand beyond the scale they dealt with. Even traders who are doing good business do not see many opportunities for scaling it up and rather think they could invest their profits from vegetables businesses in other types of business and sectors. This is quite in line with the idea of reluctant entrepreneurs by Banerjee and Duflo (2012) and it prevents the value chain from developing value added produce or reaching out into new markets. The absence of growth projects could even reflect a sense of shame at playing a role that is sometimes stigmatised. Traders in the focus group did not mention cultural stigma against traders as a significant challenge for their businesses, but nonetheless reported that this bias does exist. A cultural bias against traders was detected in some circumstances among public officers who represented traders as exploitative middlemen. This might be due to the attempt to explain why many African farming households experience food insecurity and vulnerability, with middlemen identified as part of the problem rather than part of the potential solution.

Conclusion

The analysis has shown that the local markets of indigenous leafy vegetables, in which the traders who buy at the farm gate play a main role, are characterised by a certain degree of competition and efficiency. Competition is ensured by the presence of alternative buyers in all the areas considered by the study and efficiency is a necessary condition, with one single trader handling the produce from the farm gate to wholesale, and even beyond when they have direct regular buyers. Moreover, traders were found to bear high risk due to perishability and the challenging conditions of roads and transports. It was also found that a coordination effort was necessary in many cases, to send motorbike taxi (*boda-boda*) or to keep in touch through mobile phone and that, while the technical skills required to perform such tasks are quite basic, still they might be beyond the reach of many farmers, while the time devoted by traders to their business was basically full-time, making it scarcely compatible with other activities. These considerations point to the complexity, and in a sense to the dignity, of the function performed by traders, who were found to be mostly women. Direct access by farmers to local urban markets of leafy indigenous vegetables is seldom found, as transferring implied risks and costs to traders is considered a better solution.

It should be noted that such findings are not necessarily in contrast with findings from the market access and farmers collective action literature, which has recognised the huge challenge of creating capacity among farmers, coping with poor transport infrastructure, and ensuring horizontal and vertical coordination. Part of this literature recognises that the scope for direct market access is limited to high value crops and outlets, like supermarkets (Berdegué, 2001; 2002) or to non-perishable crops (Coulter, 2007; Hellin *et al.,* 2009) and that the skills necessary for marketing are beyond the reach of individual farmers (Stringfellow *et al.,* 1997).

However, it must be said that sometimes the rhetoric of direct market access being the ideal solution for farmers extends beyond what the evidence from the literature can support, and it ends up reinforcing a kind of stigma against traders and middlemen. The role played by small traders is important for sustainable food value chains, for agricultural transformation, and agro-based industrialisation, in line with the Malabo declaration. When looking for actors to be targeted and supported for agribusiness promotion, local traders buying at the farm gate should be given much more consideration, because they are already operating and they are better positioned than farmers to develop the value chain further, and thus improve the welfare of all actors involved. However, they are not targeted by business development support services or development projects. The study extends findings by Sitko and Jayne (2014) to a value chain which is very different from that of grains and where the need for specialist businesspeople to connect production and markets is further emphasised by the perishability of the produce.

Acknowledgements

The author acknowledges the contribution by Gianni Vaggi to the fieldwork and to the interpretation of results. The author also acknowledges she received a post-doc grant in 2018-2019 at the University of Pavia with funding from the Italian Ministry MIUR, (Fondo Integrativo Speciale per la Ricerca, FISR; CUP: H42F16002450001) for the SASS project. There is no role of the funding body in the design of the study and collection, analysis, and interpretation of data and in writing the manuscript.

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Soo-Eun KIM* and Jun Ho SEOK**

Impact of consumer confidence on pork prices in Korea, taking into account the quality difference: a comparison between imported frozen and domestic chilled pork belly

This study empirically explores the impact of consumer confidence on frozen and chilled pork belly prices in Korea, taking the quality difference into account. For our analysis, we utilise the vector error correction model (VECM) and impulse-response function. Based on the weak exogenous test results, we find that consumer confidence has a long-run causality on frozen and chilled pork belly prices in Korea. The cointegration vector from VECM also shows that consumer confidence has a positive and negative effect on high- (chilled pork belly) and low-quality food (frozen pork belly) prices, respectively. Impulse-response function results reveal that chilled pork belly prices are affected by consumer confidence more frozen pork belly prices. Our findings have implications for Korean pig meat farmers as well as importers. First, consumer confidence, a leading composite index for the future, is important for high-quality pork, particularly chilled pork belly. In turn, pig-raising farmers that produce chilled pork belly may improve their profits by setting the number of pigs they raise based on the consumer confidence index. Second, importers of frozen pork belly can enhance their profits by choosing their import volume based on the consumer confidence index. Our results confirm that consumer confidence affects the demand for both high- and low-quality pig meat (chilled and frozen pork belly, respectively).

Keywords: consumer confidence, food quality, price, impulse-response function, vector error correction model

JEL classification: Q13

* Jeonbuk Institute, 1696 Kongjwipatjwi-ro, Wansan-gu, Jeonju-si, Jeollabuk-do, 55068 Republic of Korea.

** Department of International Trade, Jeonbuk National University, 567 Baekje-daero, Deokjin-gu, Jeonju-si, Jeollabuk-do, 54896 Republic of Korea. Corresponding author: junhoseok@jbnu.ac.kr

Received: 22 May 2022; Revised: 9 June 2022; Accepted: 14 June 2022.

Introduction

Keynesian economists have emphasised the role of demand on economic growth rather than the role of supply (Barbosa-Filho, 2001). Thus, consumption behaviour can be considered an important factor for short- and long-run macroeconomic policies based on the Keynesian framework. Juhro and Iyke (2020) suggest two possible explanations for the crucial role of consumption behaviour in macroeconomic policies. First, business cycles are highly affected by consumption, thereby affecting short-run macroeconomic policies (Juhro and Iyke, 2020). Second, savings, which are highly related to investment, are largely determined by consumption decisions, given that savings are part of the income not allocated to consumption according to Keynesian economics. In turn, macroeconomic policies for sustainable economic growth are affected by consumption. In other words, consumption is expected to have an impact on macroeconomic activities in terms of the government and individual spheres. In these contexts, determining the important factors for the future household consumption level is one of the crucial issues for macroeconomic policymaking (Juhro and Iyke, 2020).

Households' decisions concerning future consumption have been analysed mainly according to two views. The first is the so-called animal spirits view, which explains future consumption by connecting consumer confidence with macroeconomic performance (Ahmed and Cassou 2016). Notably, consumer confidence effects based on animal spirits cause only temporary consumer spending (Ahmed and Cassou, 2016). The second view is related to the permanent income hypothesis, which also links consumer confidence and future consumption. According to this hypothesis, the uncertainty in future incomes is highly related to the prediction of future consumption (Dees and Soares Brinca, 2013).

Many studies have examined the relationship between consumer confidence and macroeconomics from an empirical perspective. Dees and Soares Brinca (2013) explore the linkage between consumer sentiment and consumption expenditures using the consumer index of the US and the Euro area. Their findings show that the consumer confidence index has a strong predictive power on consumption under certain conditions. Ahmed and Cassou (2016) report that consumer confidence in the US has a different effect on spending according to bad and good economic times as well as types of purchase. Kilic and Cankaya (2016) also present that consumer confidence index in the US has a strong relation with personal consumption expenditure and housing market factors. Juhro and Iyke (2020) find that consumer and business confidence indexes have a prediction power on consumption expenditure in Indonesia.

Meanwhile, few studies have examined consumer confidence in the agricultural sector. Garcia-Fuentes *et al*. (2014) show that a reduction in the consumer confidence level for food safety has a negative effect on food companies' stock price. The results of Sønderskov and Daugbjerg (2011) demonstrate that consumer confidence in eco-labelling is highly related to countries' participation in eco-labelling according to survey data from the US, the UK, Denmark, and Sweden. However, the present authors have found no empirical study for consumer confidence and agricultural prices.

Given the possibly high correlation between consumer confidence and expenditure (Dees and Soares Brinca 2013), consumer confidence is expected to have an impact on c ommodity prices via changes in demand. The prices of manufacturing and service products may not easily change with respect to changes in consumer confidence due to menu prices. In contrast, the prices of fresh agricultural products can be easily changed by a change in consumer confidence; agricultural prices are determined daily. The prices for agricultural products are important to three players: the government, consumers, and farmers. The main objective of the central bank is to ensure the stability of the consumer price level. In turn, agricultural prices are important to the government. As the consumer price level is related to the real income of consumers, agricultural prices are crucial to consumers. To farmers, agricultural prices are directly related to their farm income. In this sense, agricultural prices are important to farmers.

Therefore, consumer confidence is expected to have an impact on agricultural prices via changes in demand. Agricultural prices are important to all market players. However, previous studies have not covered this topic empirically. In our study, we investigate the causal relationship between the consumer confidence index, the domestic chilled pork belly price, and the imported frozen pork belly price in Korea. To explore these causal relations, we utilise the vector error correction model (VECM) and impulse-response function.

We focus on Korea given that agricultural prices in Korea are expected to be highly affected by changes in demand. Korea is one of the net agricultural importers, according to the data of the Korea Agro-Fisheries & Food Trade Corporation, and is one of the small open-economy countries (Chung *et al*., 2007), which implies that change in domestic agricultural prices attributable to domestic demand shock may not be easily adjusted by domestic supply management. Our study also concentrates on pork prices since Korea's livestock share of agricultural GDP was 39.4% in 2018 according to Statistic Korea. Moreover, pork's share of livestock production was the largest, representing 44.4% in 2018 according to the same source.

We analyse pork belly prices, taking into consideration the high share of pork belly among pork products. According to the 2019 Food Consumption Behaviour Survey Statistics Report that is published by the Korea Rural Economic Institute, the pork belly share in pork sold for roasting was 70.5% in 2018. In addition, we divide prices of pork belly into chilled and frozen pork belly under the assumption that the impact of consumer confidence on high- and low-quality pork belly prices would be different. We can consider chilled pork belly as a high-quality product compared with frozen pork belly for two reasons. First, chilled pork belly has a higher price, which is a possible proxy variable for quality. In 2020, the average price per 100 g for domestic chilled pork belly is 2,122 KRW, whereas that for imported frozen pork belly is 1,078 KRW according to the Korea Agro-Fisheries & Food Trade Corporation. While most chilled pork belly that is distributed in Korea is domestically produced, most frozen pork belly that is distributed in Korea is imported. Second, the distribution time for chilled meat is expected to be lower than that for frozen meat. According to Zhang *et al*. (2003), food quality decreases over time. In turn, the quality of chilled pork belly is expected to be higher compared with frozen pork belly. Our hypothesis is that higher consumer confidence leads to an increase in demand for chilled pork belly over frozen pork belly. In other words, an increase in consumer confidence may have a positive effect on chilled pork belly prices. Meanwhile, an increase in consumer confidence is negatively associated with frozen pork belly prices: a decrease in demand for frozen pork belly would be reversed by an increase in demand for chilled pork belly.

Our approach is expected to contribute to the literature on consumer confidence and macroeconomic consequences in several ways. First, this study is the first to clarify the linkage between consumer confidence and agricultural prices. Second, we test whether agricultural quality affects the impact of consumer confidence on agricultural prices. Lastly, we derive policy implications based on our findings. Given that the consumer confidence index is a leading composite indicator, policymakers may formulate corresponding policies to manage the agricultural price level by determining the impact of the consumer confidence index on pork belly prices. Furthermore, pig farmers might derive optimal breeding data to maximise their profits in line with market prices.

How the consumer confidence index affects agricultural prices

According to the Organisation for Economic Co-operation and Development (OECD), the consumer confidence index provides information for future consumption as well as the savings of households. The consumer confidence index is measured by factors such as households' expected financial status, unemployment, capability for saving, and belief regarding general economic conditions. If the consumer confidence index is higher than 100, then consumers are expected to spend more on their main purchase in the following year. This scenario indicates an optimistic view of consumers on the future economic situation. However, if the consumer confidence index is less than 100, then consumers have a negative view on the future economic status. In turn, consumers are inclined to spend less in the following year.

In other words, the consumer confidence index can be classified as a leading composite indicator in terms of the consumer side. In turn, the improvement or deterioration of the consumer confidence index can be expected to be associated with future consumer expenditures. Experts have deemed it trivial, since the propensity to consume is affected by consumer trust regarding the future. Desroches and Gosselin (2002) have reported on the usefulness of the consumer confidence index on consumption. Other studies have focused on the impact of the consumer confidence index on expenditures. Dees and Soares Brinca (2013) explore the effect of consumer confidence on consumption expenditures in the US and Euro area. Kilic and Cankaya (2016) find that consumer confidence has a critical effect on consumer expenditure per person in the US. Similarly, Juhro and Iyke (2020) show the predictive power of consumer and business confidence on consumption expenditure in Indonesia. In turn, we conclude that the consumer confidence index is associated with demand shift.

The impact of consumer confidence on expenditure for agricultural products is different from that of other manufacturing goods. The reason is the upper limit on the food or nutrition intake per person. In turn, changes in consumer confidence are expected to have an impact on the proportional effect on food expenditure according to food quality. For example, if consumer confidence improves, then consumers may buy more higher-quality foods that are expensive compared with lower-quality foods. Figure 1 clearly shows that the demand change being caused by consumer confidence enhancement may have different effects on food prices according to food quality. While demand for high-quality food increases, demand for low-quality food decreases after the improvement of consumer confidence. The prices of high-quality food price thus increase from P_1 to P_2, whereas those of low-quality food decrease from P_3 to P_4. In other words, although a person's food volume intake does not change with the improvement or deterioration of consumer confidence, the share of high- and low-quality foods in their expenditure can be affected by the consumer confidence. Huang and Gale (2009) show that food unit value has increased with the increase in incomes in China. Kim *et al*. (2018) also support the proportional effect of the consumer confidence index on food expenditures – higher-income groups in the US consume more organic foods with higher unit prices. Alviola and Capps (2010) also find that organic and conventional milk are substitutable based on their estimated cross-price elasticities.

Therefore, changes in consumer confidence may have different effects on food prices based on food quality by the path of demand or expenditure change. This point is crucial to consider, given that agricultural prices determine farm income levels. Assuming a stable cost function, a change in price determines the profit margins of farmers. In turn, determining the impact of consumer confidence on prices of high- and low-quality agricultural products is helpful to the selection of the optimal agricultural production level according to product types based on quality. Moreover, exploring the impact of consumer confidence on the prices of different-quality agricultural products may contribute to farmers' profit maximisation.

Data and Methods

This study collects data on the consumer confidence index from the OECD. The price data for chilled pork belly are based on domestic values, whereas those for frozen pork belly are from imported price values. Nearly all (95.6%) of the imported pork in Korea was frozen pork in 2018 according to the Ministry of Agriculture, Food and Rural Affairs. In addition, domestically produced pork in Korea is distributed as chilled pork rather than as frozen pork owing to high price of chilled pork. Specifically, we collect the data for chilled and frozen pork belly from the Korea Agro-Fisheries & Food Trade Corporation. Detailed information on our data for the analysis is presented in Table 1.

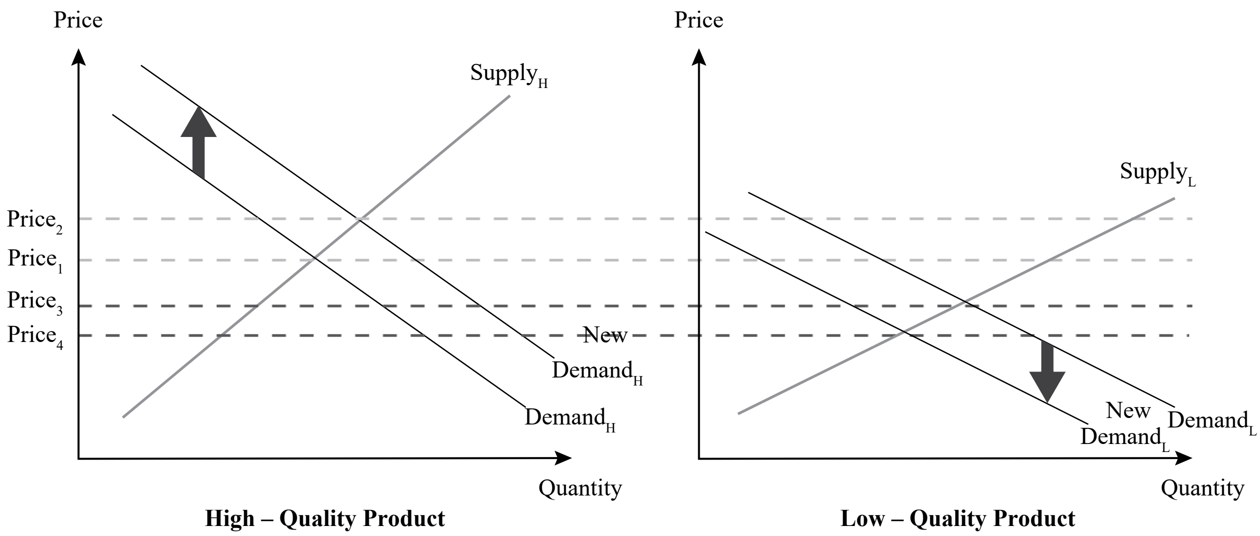

Figure 1: Possible different price effects of consumer confidence improvement on high- and low-quality food.
Source: Own composition

Table 1: Detailed information for data.

Variable	Data period	Data source	Explanation
Consumer confidence	2012–2020 (Monthly)	OECD	Consumer confidence index
Chilled Pork	2012–2020 (Monthly)	Korea Agro-Fisheries & Food Trade Corporation	Domestic chilled pork belly price (KRW/100 g)
Frozen Pork	2012–2020 (Monthly)	Korea Agro-Fisheries & Food Trade Corporation	Imported frozen pork belly price (KRW/100 g)

Source: Own composition

Figure 2 presents the trend of our variables. The volatility of imported pork belly prices is small, whereas the variation of domestic pork belly prices is large. Considering the relatively high variation in the consumer confidence index, the effect of demand factors on the prices of pork belly is expected to be relatively high for domestic pork belly. Table 2 reports the descriptive statistics for our variables using natural logarithms.

To analyse the causal relationship between the consumer confidence index and prices of domestic chilled pork belly and imported frozen pork belly in Korea, this study utilises several tests and model estimations. First, we perform the stationary test for our three variables with the Augmented Dicky Fuller (ADF) test (Dickey and Fuller, 1979) and the KPSS test (Kwiatkowski *et al.*, 1992). We use these two unit root test methods that are complementary based on the their opposite null hypotheses (Chen and Saghaian, 2016). The null hypothesis for the ADF test is non-stationary in time-series data, whereas that for the KPSS test is stationary in timeseries data. Next, we utilise the Johansen cointegration test (Johansen, 1988). We apply the VECM in the case of a long-term relation among consumer confidence index, domestic chilled pork belly price, and imported frozen pork belly price. Moreover, we also adapt the impulse-response function to analyse the detailed relationship between the consumer confidence index and the prices of domestic chilled and imported frozen pork belly.

To examine for long-term relations based on the Johansen cointegration test, we begin with a vector auto regressive (VAR) model, given as the following equation:

$$Y_t = \mu + \sum_{n=1}^{k} \Pi_n Y_{t-n} + \varepsilon_t \qquad (1)$$

where Y_t is a 3×1 vector of ln(*Confidence*), ln(*Chilled*), and ln(*Frozen*); μ represents a 3×1 constant vector; 3×1 parameter matrices are presented as Π; k indicates the number of lags; and ε_t follows i.i.d. $N(0,\delta^2)$. Equation (1) can be transformed with the error correction form to the following:

$$\Delta Y_t = \mu + \Pi Y_{t-1} + \sum_{n=1}^{k-1} \Gamma_n \Delta Y_{t-n} + \varepsilon_t \qquad (2)$$

where Δ is the first difference, t indicates the time dimension, Π is defined as $\Pi_1 + \Pi_2 + \cdots + \Pi_{k-1} - I$, and Γ_k is defined as $-\sum_{j=k}^{p} \Pi_j$. Π, the long-term matrix, can be decomposed to an adjustment vector (α) and cointegration vector (β). Specifically, α is the 3×r vector that presents the speed of adjustment of ln(*Confidence*), ln(*Chilled*), and ln(*Frozen*) towards long-term equilibrium. β is the r×3 cointegration vector that represents a linear relation between ln(*Confidence*), ln(*Chilled*), and ln(*Frozen*) in the long-term equilibrium.

To perform the Johansen cointegration test for finding rank r, we utilise likelihood ratio (LR) test statistics. We

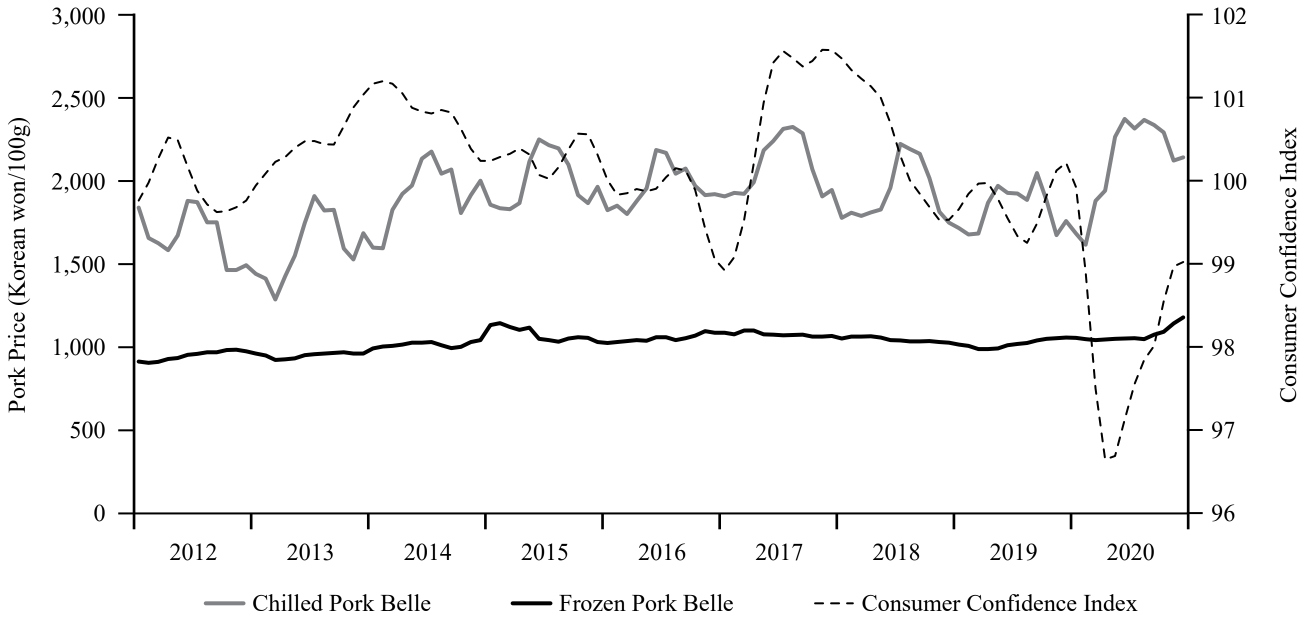

Figure 2: Trends in the variables (level data).
Source: OECD and Korea Agro-Fisheries & Food Trade Corporation

Table 2: Descriptive statistics.

Variable	Observations	Mean	Std. dev.	Min	Max
ln(*Confidence*)	108	4.606	0.010	4.571	4.621
ln(*Chilled*)	108	7.547	0.128	7.164	7.776
ln(*Frozen*)	108	6.939	0.053	6.812	7.077

Source: Own composition

employ the trace test ($LR(\lambda_{trace}) = -T\sum_{i=r+1}^{k}\ln(1-\lambda_i)$). The null hypothesis of rank r for the cointegration equations is rejected if the LR test statistics is higher than the critical value suggested by Osterwald-Lenum (1992). If the variables show a cointegration relation, then ΠY_{t-1} can be represented as $\alpha\beta' Y_{t-1}$. Furthermore, we can define $\beta' Y_{t-1}$ as the error correction term (ECT_{t-1}) that indicates the deviation from the long-term equilibrium at time *t-1*. We can derive the long-term causality based on the *t*-test for the coefficients of adjustment vector α. This long-term causality test is also called the weak exogeneity test (Chen and Saghaian, 2016).

Empirical Results

The results of the stationary test based on the ADF and KPSS are reported in Table 3. Our three variables, namely, ln(*Confidence*), ln(*Chilled*), and ln(*Frozen*), are not stationary for the level data used in both unit root tests. The first difference of ln(*Confidence*), ln(*Chilled*), and ln(*Frozen*) do not have an unit root according to the ADF and KPSS tests at the 10% significance level. In other words, ln(*Confidence*), ln(*Chilled*), and ln(*Frozen*) are shown to be $I(1)$ in the level data and $I(0)$ in the first difference data according to both unit root tests. In turn, we can apply the Johansen cointegration test on our three variables.

The results of the tri-variate (ln(*Confidence*), ln(*Chilled*), and ln(*Frozen*)) Johansen cointegration tests based on the trace statistics are given in Table 4. The null hypothesis that the three variables are not cointegrated is rejected at the 1% significance level. The null hypothesis that the rank of ln(*Confidence*), ln(*Chilled*), and ln(*Frozen*) is, at most, 1 is not rejected at the 5% significance level. In turn, we can conclude that ln(*Confidence*), ln(*Chilled*), and ln(*Frozen*) have a long-term relation with one cointegration vector.

The results of the tri-variate VECM are presented in Table 5. The coefficient of the speed of adjustment for the equation Δln(*Confidence*) is not significant at the 10% significance level. In turn, we can interpret this result as

Table 3: Stationary tests results.

Tests	Variables	With trend	Without tend
ADF	ln(*Confidence*)	-2.267	-1.624
	ln(*Chilled*)	-1.571	-1.326
	ln(*Frozen*)	-2.756	-2.014
	Δln(*Confidence*)	-5.044***	-4.638***
	Δln(*Chilled*)	-4.618***	-4.638***
	Δln(*Frozen*)	-4.095***	-4.204***
KPSS	ln(*Confidence*)	0.222***	0.603**
	ln(*Chilled*)	0.174**	0.774***
	ln(*Frozen*)	0.331***	1.130***
	Δln(*Confidence*)	0.030	0.060
	Δln(*Chilled*)	0.027	0.028
	Δln(*Frozen*)	0.092	0.089

Note: *P<0.1, **P<0.05, ***P<0.01. The optimal lag of ADF is chosen based on the Akaike information criterion.
Source: Own composition

Table 4: Results of the Johansen cointegration test.

Null hypothesis	Trace statistics	Critical value	
		5%	1%
$H_0: r = 0$	59.274	29.68	35.65
$H_0: r \leq 1$	10.177	15.41	20.04
$H_0: r \leq 2$	1.057	3.76	6.65

Note: The optimal lag is selected based on the Akaike information criterion.
Source: Own composition

Table 5: Results of VECM.

Variables	Δln(*Confidence*)	Δln(*Chilled*)	Δln(*Frozen*)
ECT_{t-1}	-0.0005	0.0944***	-0.0159***
	(0.0004)	(0.0172)	(0.0043)
Intercept	0.0000	0.0944***	0.0023
	(0.0001)	(0.0172)	(0.0015)
Δln(*Confidence*)$_{t-1}$	1.5462***	-2.8387	1.2528
	(0.0995)	(4.6524)	(1.1614)
Δln(*Confidence*)$_{t-2}$	-1.1286***	2.5214	-2.3549
	(0.1488)	(6.9590)	(1.7372)
Δln(*Confidence*)$_{t-3}$	0.2803	0.6654	1.5627
	(0.1004)	(4.6965)	(1.1724)
Δln(*Chilled*)$_{t-1}$	0.0018	0.3405***	-0.0319
	(0.0021)	(0.0968)	(0.0242)
Δln(*Chilled*)$_{t-2}$	-0.0014	0.2361**	-0.0154
	(0.0022)	(0.1013)	(0.0253)
Δln(*Chilled*)$_{t-3}$	-0.0007	0.2905***	-0.0805***
	(0.0022)	(0.1009)	(0.0252)
Δln(*Frozen*)$_{t-1}$	-0.0012	-0.2867	0.2862***
	(0.0081)	(0.3776)	(0.0943)
Δln(*Frozen*)$_{t-2}$	-0.0008	-0.4170	0.1566
	(0.0085)	(0.3988)	(0.0995)
Δln(*Frozen*)$_{t-2}$	0.0044	-0.3612	-0.0381*
	(0.0085)	(0.3966)	(0.0990)
Cointegration Vector		(1 -4.45 8.36)	

Note: *P<0.1, **P<0.05, ***P<0.01. Numbers in parentheses indicate standard error values.
Source: Own composition

follows: frozen and chilled pork belly prices do not have a long-term causality with respect to the consumer confidence index based on the weak exogeneity test. However, the coefficients of the speed of adjustment for the equations Δln(*Chilled*) and Δln(*Frozen*) are significant at the 1% significance level. In other words, the consumer confidence index has a long-term causation on chilled and frozen pork belly prices according to the weak exogeneity test. In addition, chilled and frozen pork belly prices have a bi-directional long-term causality based on the weak exogeneity test. The sign for the coefficients of the speed of adjustment for the equations Δln(*Chilled*) and Δln(*Frozen*) are opposite, with the former being positive and the latter, negative. In turn, the exogenous shock of the consumer price index has a deviation effect from the and an adjustment effect towards long-term equilibrium on chilled and frozen pork belly prices, respectively.

Our estimated cointegration vector gives more important information. The consumer confidence index has a positive effect on chilled pork belly prices and a negative effect on frozen pork belly prices according to the cointegration vector. The cointegration vector implies that consumers' positive view on future economic situation has a positive effect on the price of chilled pork belly but a negative one the price frozen pork belly. This result supports our hypothesis that enhanced consumer confidence has a positive effect on high-quality food prices and a negative effect on low-quality food prices.

To validate that the number of cointegrating equations is correctly specified, this study also examines the stability condition. If all characteristic roots are located in the unit circle, then the stability condition is satisfied (Asgari *et al.*, 2020). To check that all characteristic roots are in the unit circle, we plot the roots of the companion matrix. Figure 3 reports that all characteristic roots are within the unit circle, indicating satisfactory stability.

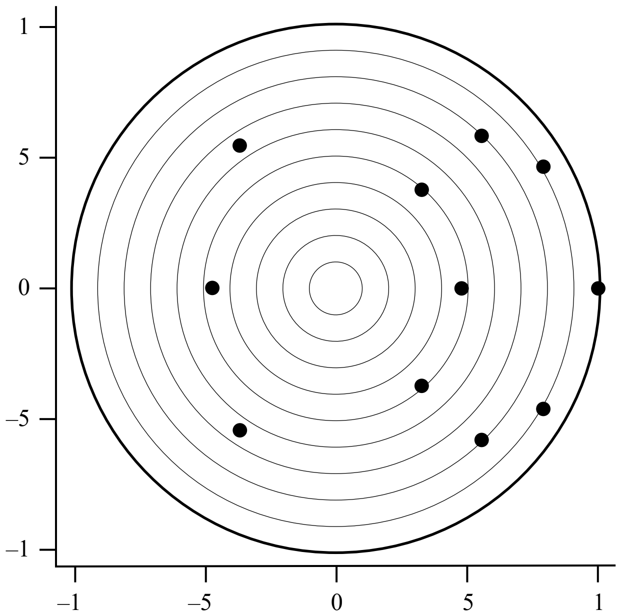

Figure 3: Estimated VECM of characteristic roots of the polynomial.
Source: Own composition

We also operate the short-run Granger causality test based on the Wald test. The results of the short-run Granger causality test are presented in Table 6. Only chilled pork belly prices have causal effect on frozen pork belly prices in terms of Granger causality among the three variables. This result indicates that domestic chilled pork belly prices have a price leadership on imported frozen pork belly price in the short run. Given that imported frozen pork belly prices are set by a prior contract between importers and exporters, the short-run price variation source might be attributed to domestic chilled pork belly prices.

Figure 4 reports the results of two causality tests: the weak exogenous test and short-run Granger causality test. In the long term, consumer confidence drives the prices of chilled and frozen pork belly. Meanwhile, consumer confidence does not have a short-run Granger causality on chilled and frozen pork belly prices. The prices of both chilled and frozen pork belly have a bi-directional causality in the long run, whereas only chilled pork belly prices have a uni-directional Granger short-run causality on frozen pork belly prices. Based on these causalities, we also perform the impulse-response function.

We focus on the impulse-response function of the consumer confidence index on pork belly prices and that between chilled and frozen pork belly prices. Specifically, we utilise the orthogonalized impulse-response function for tracing dependent variables' (chilled and frozen pork belly prices) responses in the VECM to shocks to all three variables (chilled pork belly price, frozen pork belly price, and

Table 6: Results of the short-term Granger causality test.

Null hypothesis	Chi-square	P-value
Confidence ↛ Chilled	1.32	0.73
Frozen ↛ Chilled	3.37	0.34
Confidence ↛ Frozen	1.96	0.58
Chilled ↛ Frozen	11.15**	0.01
Chilled ↛ Confidence	1.34	0.72
Frozen ↛ Confidence	0.29	0.96

Note: *P<0.1, **P<0.05, ***P<0.01.
Source: Own composition

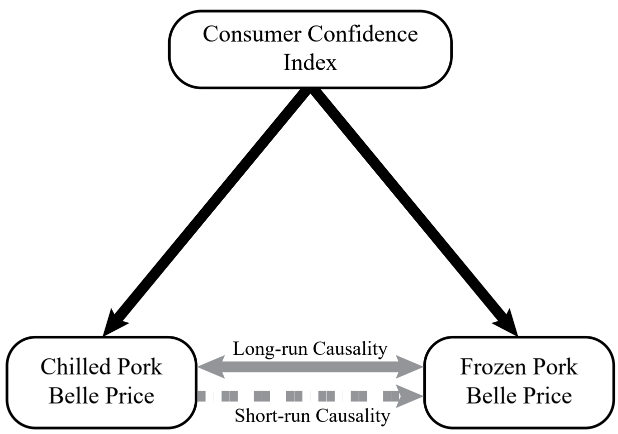

Figure 4: Short- and long-term causality (5% significance level).
Source: Own composition

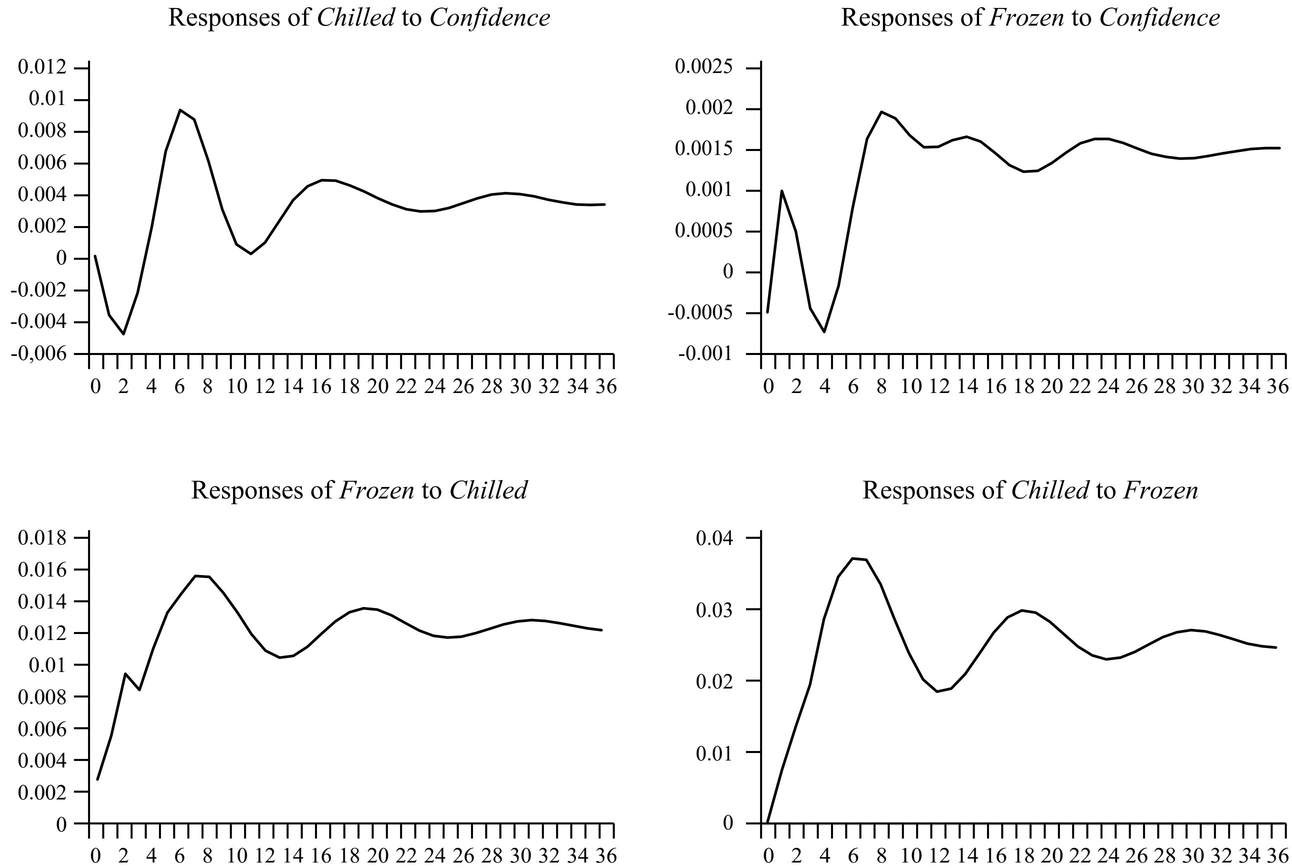

Figure 5: Impulse responses of Cholesky 1 SD innovations (36-month horizon).
Source: Own composition

consumer confidence index). The impulse-response function of interest in this study is presented in Figure 5. The impact of the consumer confidence index on chilled pork belly prices is higher compared with frozen pork belly prices. This result supports the idea that high-quality food is highly affected by consumer confidence index shock compared with low-quality food. The innovation shock of frozen pork belly prices on chilled pork belly prices is higher than vice versa.

Conclusion and Implications

This study empirically investigates the impact of the consumer confidence index on domestic chilled and imported frozen chilled pork belly prices in Korea. By employing VECM and the impulse-response function for exploring the causal relation among consumer confidence, chilled pork belly price, and imported pork belly price, we test the hypothesis that consumer confidence has a different effect on the prices of qualitatively different food considering the limits in the food intake per person. Specifically, this paper assumes that consumer confidence has a positive and a negative effect on high- and low-quality food, respectively.

The VECM results show that consumer confidence has a long-term causality on chilled and frozen pork belly prices based on the weak exogenous test. The cointegration vector presents that consumer confidence has a positive and a negative effect on the prices of chilled and frozen pork belly, respectively. Given that chilled pork is higher-quality food compared with frozen pork, our research hypothesis is supported by our results. We also find a bi-directional long-term causality between chilled and frozen pork belly prices. Results of the short-run Granger causality test indicate a uni-directional causality of chilled pork belly price on frozen pork belly price. Based on these long- and short-term causalities, we perform the impulse-response function. The innovation shock of consumer confidence on pork belly prices is high in the chilled compared with the frozen type. In turn, the impulse-response function results also support the idea that high-quality food prices are more affected by consumer confidence compared with low-quality food.

Our results have the following implications. First, consumer confidence, a leading composite index for the future, is important for high-quality pork, particularly chilled pork belly. In turn, pig-raising farmers that produce chilled pork belly may improve their profits by setting the number of pigs they raise based on the consumer confidence index. Second, importers of frozen pork belly can enhance their profits by choosing their import volume based on the consumer confidence index. Our results confirm that consumer confidence affects the demand of high- and low-quality pig meat (chilled and frozen pork belly, respectively).

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Short communication

Myrna van LEEUWEN*, Ana Rosa GONZALEZ-MARTINEZ* and Viktoriya STURM**

Developing BioMAT: A new conceptual framework to model the market of bio-based materials in the EU

The supply and use of bio-based products may yet shape the future, contributing to the achievement of broader objectives such as climate neutrality, circularity, and sustainability. Reducing dependency on non-renewable resources, and substituting fossil-based resources with biomass by way of a transition to a sustainable industrial – and especially chemical – sector, represent important challenges. To be able to understand what may be desirable pathways to a 'green' chemical sector, insights on the upcoming needs of biomass for the EU bio-based industry are required, together with information about its availability and the way it is produced. However, there is a lack of methodologies and quantitative tools capable of assessing and anticipating potential developments in the EU bio-based markets. To provide an early theoretical basis for the upcoming modelling of supply chains of the bio-based materials market, this short communication presents the conceptual framework underlying the BioMAT (Bio-based MATerials) model, developed in the course of the EU H2020 BioMonitor project.

Keywords: Bioeconomy, bio-based products, biomass feedstock, EU markets outlooks, partial-equilibrium (PE) modelling, BioMAT.

JEL classifications: Q01, Q02, Q11.

*Wageningen Economic Research, 6708 PB Wageningen, The Netherlands. Corresponding author: ana.gonzalezmartinez@wur.nl

**Johann Heinrich von Thünen-Institut, Bundesallee 50, 38116 Braunschweig, Germany.

Received: 03 May 2022; Revised: 25 May 2022; Accepted: 31 May 2022.

Introduction

Contemporary challenges such as climate change, the unsustainable rhythm at which natural resources are deployed, the generation of waste or the provision of healthy food for all ought to be a key preoccupation for policymakers. In general terms, these challenges demand for a new paradigm in which all participants in the food system play more 'sustainable' roles. Thinking about sustainability, one can think of the model proposed by Raworth (2017), i.e. the so-called 'doughnut model' which puts together environmental and socio-economic challenges in a coherent and balance manner. As pointed by Raworth (2017), 'humanity's 21st century challenge is to meet the needs of all within the means of the planet'. This statement can be translated into the 'doughnut' which is defined by an outer circle representing the environmental ceiling, as well as an inner circle which is defined by social foundations as determined in the context of the Sustainable Development Goals (SDGs).[1] An interesting aspect of the 'doughnut model' is the richness of elements that it integrates: housing, gender equality, food, income, biodiversity, climate change, air pollution, land conversion, etc. According to Raworth (2017), the target should be on 'staying within the doughnut' rather than pursuing economy growth. In other words, the focus should be on staying within 'the safe and just space for humanity' which reflects a 'sustainable' position for the entire economic system.

Teodorescu (2015) suggests that 'sustainable development is meant to be the summation of economic, environmental and social considerations for the present and especially for the future'. Along the same lines, Dyngeland *et al.* (2020) emphasise that there is a need for further analysis of the interactions between the social and environmental outcomes of sustainable development policies, this being particularly relevant when assessing progress towards achieving the SDGs. Moreover, Chavarria *et al.* (2020) indicate that the bioeconomy is an important option when working towards the achievement of the SDGs. In particular, the substitution of fossil-based resources that are used for energy supply and industrial purposes with bio-based ones could contribute towards making the economy more sustainable and efficient from a resource utilisation perspective. The same source also highlights the importance of the bioeconomy for achieving objectives linked to food security and nutrition, health, and well-being, as well as clean water and sanitation.

As defined by European Commission (2012, 2018), the bioeconomy is 'the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy. Its sectors and industries have strong innovation potential due to their use of a wide range of sciences, enabling industrial technologies, along with local and tacit knowledge'.[2, 3] European Commission (2013) also indicates that a transition towards a bio-based economy is required to provide a suitable response to problems such as food security, energy security, the high dependence on fossil-based resources, and the increasing demand of biological sources for production of bio-based materials, among others. This transition is also the appropriate response to sustainability concerns related to GHG emissions, excessive waste,

[1] See Luukkanen *et al.* (2021) for an application quantifying the doughnut economy with the sustainability window method in the case of Thailand.

[2] Further details are available at: https://ec.europa.eu/research/bioeconomy/pdf/bioeconomycommunicationstrategy_b5_brochure_web.pdf.

[3] Ronzon *et al.* (2020) estimate that the bioeconomy generated around €614 billion of value added in 2017 which is equivalent to 4.7% of the EU27 GDP, while creating jobs for 9% of the EU27 workforce.

environmental sustainability of primary agriculture, increasing competition for land, etc. To really contribute to better climate conditions, biomass must be produced along two key sustainability principles, which are mainly the avoidance of: (i) LULUC effects, e.g. deforestation; and (ii) competition with biomass usages for food. In the action plan of EC's Bioeconomy Strategy (European Commission, 2018), it is mentioned that the development of the bioeconomy should be monitored and analysed to understand if multiple targets develop in the right direction and at sufficient speed. However, there is a lack of methodologies and quantitative tools which permit to assess and anticipate the potential developments of the EU bio-based markets. Against this background, this short communication aims at expanding the existing body of knowledge by presenting a consistent conceptual framework for analysis of the value chain of bio-based materials in the EU and its Member States. This conceptual framework constitutes the theoretical underpinnings of the BioMAT (Bio-based MATerials) model, developed over the course of the EU H2020 BioMonitor project.[4]

Literature review

When looking at the development of the bio-based economy and its potential expansion, the demand side is due some consideration. This is the case since consumers are not fully aware about the availability and characteristics of the bio-based choices that are at hand when trying to adopt a 'more sustainable' consumption pattern. To make the point, we refer to a comprehensive study (Hempel *et al.,* 2019) on the societal acceptance of a bio-based economy in Germany. Hempel *et al.* (2019) show that consumers generally have a positive attitude towards the consumption of bio-based products. However, citizens seem to need more information and background knowledge to make their decisions, asking the relevant support from policymakers. Moreover, Sijtsema *et al.* (2016) look at individuals' perceptions regarding the broad concept of 'bio-based' and a particular selection of bio-based products. This piece of research has revealed that the concept of 'bio-based' is still an unfamiliar notion for many. Individuals' perceptions regarding 'bio-based' are quite mixed. The concept was related to both positive and negative environmental aspects, which gives some evidence on the lack of knowledge and information that consumers have. All these findings emphasise the need for further public interventions to facilitate the adoption of new consumption habits, as well as the development of further bio-based goods.

Therefore, for bioeconomy potentials to materialise, and apart from the technical progress on the supply side, consumer behaviour needs to change so that the transition from fossil-based products to their bio-based alternatives happens. Hence, certifications, green premiums, awareness-raising campaign, subsidies, etc. are among the tools that policymakers have at their disposal to facilitate this transition.[5] As Stern *et al.* (2018) have emphasised, it is important to make the process as inclusive as possible, the consumer being a central actor that needs to be mobilised. This process should involve all societal actors in a bottom-up manner so that they can engage with the concept of bioeconomy and contribute to the process. Focusing on green premiums and consumer behaviour, Partanen *et al.* (2020) explore the willingness of consumers to pay an additional price for the bio-based alternatives to fossil-based choices. The study concludes that bio-based options can receive green premiums that extend beyond energy applications.

Nevertheless, Diakosavvas and Frezal (2019) point out that the expansion of the bioeconomy *per se* is not intrinsically sustainable. All the participants in the bioeconomy should be aware of the existence of economic, social, and environmental trade-offs that cannot be avoided. Diakosavvas and Frezal (2019) perfectly illustrate the complexity surrounding the notion of 'bioeconomy' when concluding that 'determining the most cost-efficient use of biological and other resources to meet food, feed, fuel and fibre needs is a major challenge for private and public policy decision makers', the bioeconomy is a multidimensional system which should be studied from all angles, i.e. economic, societal, environmental, etc. Hence, its analysis needs an integrated approach comparable to the 'food systems' framework that is increasingly being used to understand and model the 'traditional' agri-food sector.[6] Calicioglu and Bogdanski (2021) indicate that the emphasis should not be on measuring how the bioeconomy develops but on measuring its sustainability. In particular, the authors also suggest that the monitoring and evaluation of the bioeconomy have coupling potential with SDG reporting particularly on the fields of biodiversity conservation, waste reuse, gender equality, inclusiveness, and international cooperation.

A final remark in terms of the gaps identified in the existing body of literature is needed. Chavarria at el. (2020) point out that there is an important knowledge gap when indicating that the transition towards a bio-based economy requires: '(i) a broader agreement on guiding principles for global bioeconomy policy making; (ii) a framework of credible bioeconomy indicators; and (iii) an effective bioeconomy knowledge management platform.' Despite the consensus around the relevance of these elements, these three aspects are important areas in which the available statistical sources and frameworks of analysis seem to lag behind. All these observations highlight the 'value added' of presenting the conceptual framework underlying BioMAT to a broader audience.

A conceptual framework for representing the EU bio-based commodity markets

Functional specification

When sketching the 'building blocks' that make up the bioeconomy, e.g. bio-based chemicals, bio-based solvents, etc., researchers should focus on understanding the key drivers of production, imports, exports, uses and prices of bio-based products (as well as the determinants

[4] See: https://biomonitor.eu/.

[5] Along the same lines, Diakosavvas and Frezal (2019) suggest that further development of the bioeconomy would require a combination of technology-push and market-pull policy initiatives that expand the demand for bio-based products. This increase in demand should happen at both public and private levels.

[6] See Gonzalez-Martinez *et al.* (2021) for further discussion on the food system approach in the case of the agri-food sector.

of their fossil-based counterparts).[7] For each of these 'building' blocks, there are four dimensions that need to be considered: countries, product applications, biomass feedstock types, and time.[8] In terms of the country dimension, this framework (and subsequently, BioMAT) considers all EU27 Member States and the United Kingdom as individual regions.[9] In addition, a 'Rest of the World' region is also modelled in order to 'close' the system. Turning to the product-application dimension, it distinguishes the following chemical applications: (i) chemical platform products; (ii) solvents; (iii) polymers for plastics; (iv) paints and oils; (v) surfactants; (vi) lubricants; (vii) adhesives; (viii) cosmetics; (ix) pharmaceuticals; (x) biofuels; (xi) food & feed; (xii) building material; (xiii) agrochemicals; (xiv) manmade fibres; and (xv) other products. In addition, the framework accounts for the following biomass feedstock types: (i) starch; (ii) industrial sugar; (iii) industrial plant oils; (iv) wood lignocellulose; (v) agricultural lignocellulose; (vi) animal biomass, (vii) aquatic biomass; and (viii) other forms of biomass. For a comprehensive modelling, it is important to consider future developments of the total market of specific products, separately representing fossil-based and bio-based alternatives. Where the time dimension is concerned, a period ending in 2030 is sufficient for a modelling tool to deliver medium-term insights, although it can also consider a longer-term horizon.[10]

Keeping in mind the categories mentioned above, Table 1 provides an overview of the key relations (equations and identities) and determinants (variables), which together comprise the present framework. As has already been advanced, this specification is used as the basis for estimating the equations that comprise the BioMAT model, covering bio-based (BCH) applications, fossil-based (FCH) alternatives and the total (TCH) market.

Table 1: Key equations/identities to be estimated when modelling the bioeconomy.

Supply equations for a given chemical application K			
Total supply chemical application *K*	$TCH\_S_{K,CC,T}$	=	$f(pf_{K,CC,T}, V_{K,CC,T})$ *pf = price indicator of application K* *V = vector of exogenous variables which have an impact on supply, e.g. policy variables, trend*
Share of bio-based formulations over total supply	$shBCH\_S_{K,CC,T}$	=	$f(cdr_{K,CC,T}, fcr_{F,K,CC,T}, V_{K,CC,T})$ *cdr = total production cost ratio of bio-based and fossil-based application K* *fcr = efficiency ratio to convert biomass feedstock into application K* *V = vector of exogenous variables which have an impact on bio-based supply share for application K*
Bio-based supply	$BCH\_S_{K,CC,T}$	=	$TCH\_S_{K,CC,T} \cdot shBCH\_S_{K,CC,T}$
Fossil-based supply	$FCH\_S_{K,CC,T}$	=	$TCH\_S_{K,CC,T} - BCH\_S_{K,CC,T}$
Demand equations for a given chemical application K			
Total demand chemical application K	$TCH\_D_{K,CC,T}$	=	$f(gdpc_{K,CC,T}, V_{K,CC,T})$ *gdpc = income per capita* *V = vector of exogenous variables which have an impact on demand, e.g. consumer preferences, policy variables, trend*
Share of bio-based formulations over total demand	$shBCH\_D_{K,CC,T}$	=	$f(pxr_{K,CC,T}, V_{K,CC,T})$ *pxr = price ratio between bio-based and fossil-based chemical application K* ($pb_{K,CC,T} / pf_{K,CC,T}$) *V = vector of exogenous variables which have an impact on bio-based demand share for application K*
Bio-based demand	$BCH\_D_{K,CC,T}$	=	$TCH\_D_{K,CC,T} \cdot shBCH\_D_{K,CC,T}$
Fossil-based demand	$FCH\_D_{K,CC,T}$	=	$TCH\_D_{K,CC,T} - BCH\_D_{K,CC,T}$

7 The experience gained in the case of modelling the agro-food value chains in AGMEMOD (Agriculture Member State Modelling) is a source of inspiration when thinking about the general structure of this framework and the interaction among key elements such as production, consumption, trade, etc. Further details on the AGMEMOD model are available at: https://agmemod.eu/.

8 The combination of these four dimensions constitutes the so-called 'modelling space'.

9 The level of detail that each country model has is highly dependent on the availability of data in the existing statistics.

10 The period is extendable to 2050 when thinking of simulating long-term scenarios.

'Closing' the market		
TCH net exports	$TCH\_NEX_{K,CC,T}$ =	$TCH\_S_{K,CC,T}$ - $TCH\_D_{K,CC,T}$
BCH net exports	$BCH\_NEX_{K,CC,T}$ =	$BCH\_S_{K,CC,T}$ - $BCH\_D_{K,CC,T}$
FCH net exports	$FCH\_NEX_{K,CC,T}$ =	$FCH\_S_{K,CC,T}$ - $FCH\_D_{K,CC,T}$
Biomass feedstock supply for material use		
Supply of feed type *F*	$BM\_S_{F,CC,T}$ =	*As calculated by the AGMEMOD model for agricultural resources; EFI-GTM for wood; S2Biom for residues*
Biomass feedstock demand for material use		
Domestic use of feed type *F* by bio-based chemical product *X* belonging to application *K*	$BM\_D^{x}_{K,F,CC,T}$ =	$BCH\_S^{x}_{K,F,CC,T} \cdot fcr^{x}_{K,F,CC,T} \cdot shf^{x}_{K,F,CC,T}$ *BCH_S = supply of feed type F for conversion into a bio-based product X belonging to application K* *fcr = feedstock conversion rate between use of biomass feedstock type F and the bio-based product X belonging to application K* *sfh = share of feedstock type F in total feedstock use of bio-based product X within application K*
Biomass feedstock net exports	$BM\_NEX_{F,CC,T}$ =	$BM\_S_{F,CC,T} – BM\_D_{F,CC,T}$ *NB.* $BM\_S_{F,CC,T}$ *and* $BM\_D_{F,CC,T}$ *are calculated by aggregating feedstock supply and domestic use for all products included in all the different applications*
Price equations		
Fossil-based application producer price	$pf_{K,CC,T}$ =	$f(kpf_{K,CC,T}, V_{K,CC,T})$ *kpf = EU price indicator of fossil-based application* *NB. If CC is the country 'setting' the price at EU level, kpf is replaced with a world market price indicator and the self-sufficiency rate of the EU for that chemical application* *V = vector of exogenous variables which have an impact on national price, e.g. oil price developments* *NB. If CC is the country 'setting' the price at EU level, V includes exchange rates and trade policies*
Bio-based application producer price	$pb_{K,CC,T}$ =	$f(kpb_{K,CC,T}, V_{K,CC,T})$ *kpb = EU price indicator of bio-based application* *NB. If CC is the country 'setting' the price at EU level, kpb is replaced with a world market price indicator and the self-sufficiency rate of the EU for that chemical application* *V = vector of exogenous variables which have an impact on national price, e.g. oil price developments* *NB. If CC is the country 'setting' the price at EU level, V includes exchange rates and trade policies*
Price biomass type *F* (national price indicator of feedstock)	$pbm_{F,CC,T}$ =	$f(kpbm_{F,CC,T}, V_{F,CC,T})$ *kpbm = price of the feedstock in the country that is the key player within the EU* *NB. If CC is the country 'setting' the price at EU level, kpbm is replaced with a world market price indicator and the self-sufficiency rate of the EU for that feedstock type* *V = vector of exogenous variables which have an impact on national feedstock prices, e.g. CAP measures* *NB. If CC is the country 'setting' the price at EU level, V includes exchange rates and trade policies*

Note: **K =** chemical products: platform chemicals, solvents, polymers for plastics, paints and oils, surfactants, lubricants, adhesives, cosmetics, pharmaceuticals, food & feed, building material, agrochemicals, manmade fibres, and other products. **T =** year, 2010-2030 (or 2050). **CC =** individual EU27 Member State, the UK and the Rest of the World (RoW). **F =** feedstock type, e.g. starch, industrial sugar, industrial plant oils, wood lignocellulose, agricultural lignocellulose, animal biomass, aquatic biomass, and other biomass. **I =** culture group, e.g. grains, oilseeds and root crops. **X =** product types, e.g. polymers for plastics includes polyacetals, other polyethers and epoxide resins, in primary forms; polycarbonates, etc.
Source: own composition.

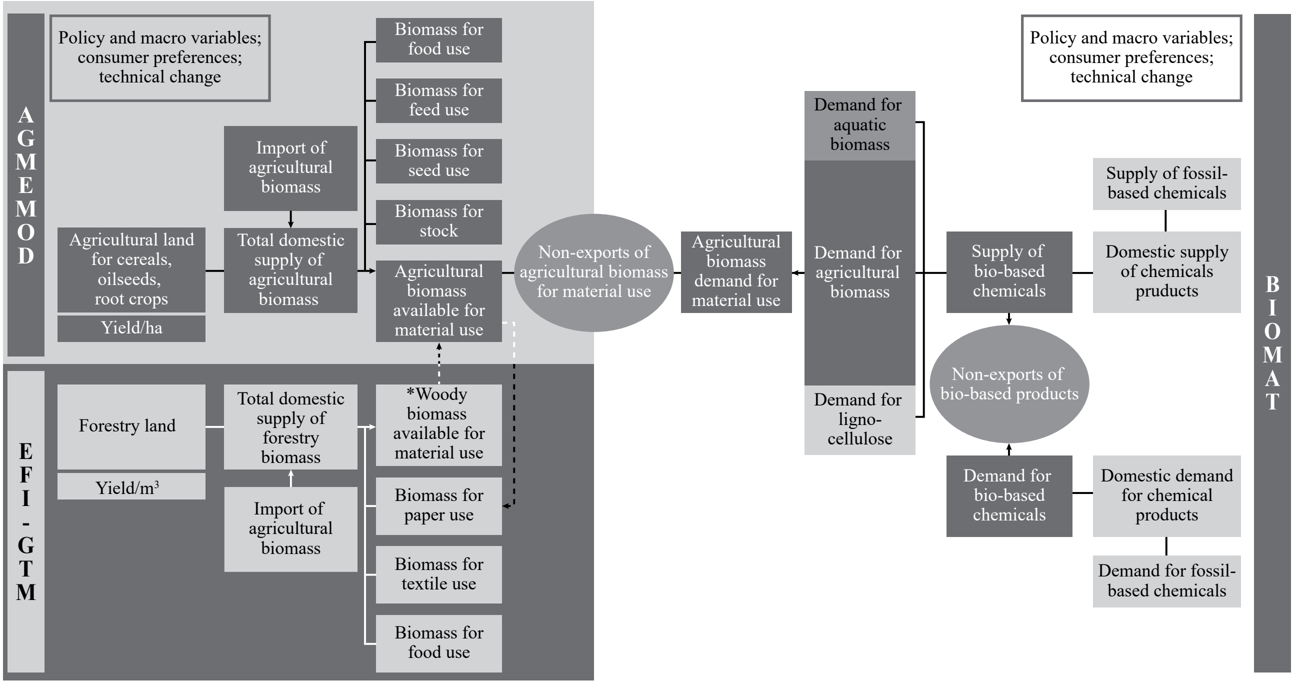

Figure 1: Integrated modelling use of AGMEMOD, EFI-GTM and BioMAT.

* For industrial sugar.

Source: own composition

The actual 'construction' of the BioMAT model will involve the estimation of more than 8000 relationships following the specification presented in the table above. A Cobb-Douglas (Cobb and Douglas, 1928) specification is used for the equations that deliver the share of bio-based formulations over the total market. To illustrate this, a generic example is provided below, which represents the case of the relative market share of a given bio-based application:

$$shBCH\_S = a \cdot cdr^{b} \cdot fcr^{c} \cdot T^{d} \quad (1)$$

with a being the intercept; while b, c and d are the relevant elasticities for the cost ratio, *cdr*, efficiency ratio, *fcr*, and the trend variable, *T*.

Further considerations

Since models are by definition a simplification of reality (van Tongeren *et al.,* 2001), there is also room for model collaboration when thinking of modelling the bioeconomy according to this framework (see e.g. Gonzalez-Martinez *et al.,* 2021). A direct 'hard' linkage (Wicke *et al.,* 2015) has been established between BioMAT and the existing AGMEMOD (Agricultural Member State Modelling) model; while it has a 'soft' linkage with the global forest and wood-based product model EFI-GTM (Figure 1).[11] The first linkage allows AGMEMOD to deliver projections on available raw feedstock for food and feed processing and industrial uses, while BioMAT feeds back the required biomass feedstock required in the material industry. BioMAT also connects to EFI-GTM by giving insights into the amount of wood lignocellulose available for material use in bio-based chemical products and feeds back the use of starch for paper production to EFI-GTM. Additional model linkages could be developed on an *ad doc* basis for the simulation of alternative scenarios.

Conclusions

A pressing issue on the policy agenda is how to monitor and assess the expansion of the bioeconomy, as well as the effectiveness of the related public interventions. The need for evidence-based policy making in this area can only be satisfied by the development of quantitative tools for analysis that represent the key elements of the supply and demand sides of the bioeconomy. Ideally these tools should also provide forward-looking insights that permit ex-ante policy assessment. As an interim step towards the 'construction' of a fully operational quantitative tool, i.e. the BioMAT model, there was a need for developing a conceptual framework identifying the most relevant elements and interactions of bio-based value chains, as concluded from the gap analysis presented in Lovrić *et al.* (2020). Sharing the 'conceptual' outcomes of the initial stages of the development of the mentioned model is of general interest since it could inspire upcoming modelling exercises that focus on the potential development of bio-based products and their contribution to achieving societal goals (like reducing dependence on non-renewable resources).

To sum up, the proposed framework explains the demand for bio-based products by means of consumer preferences and the relative prices of bio-based and fossil-based products. The supply of bio-based products explains the need for biomass feedstock, determined by the efficiency to convert biomass into bio-based chemicals, and the relative production costs of bio-based and fossil-based products among

[11] For further details on these two models, see: AGMEMOD (https://agmemod.eu/); and EFI-GTM (https://efi.int/sites/default/files/files/publication-bank/2018/ir_15.pdf).

others. This framework is flexible enough to account for (current and foreseen) policy instruments that could potentially influence the future development of the EU bio-based chemical markets, e.g. direct interventions that could affect the prices of bio-based and fossil-based materials, and therefore, change consumer preferences. When the BioMAT model is fully operational, it will also allow for the simulation of the potential impacts of interventions that mitigate climate change such as the reduced use of pesticides and fertilisers adopted in the new Common Agricultural Policy (CAP), or measures that set a CO_2 price on unsustainable production methods. In short, this framework makes it possible to assess the effects of alternative pathways of bio-based chemical markets, and thereby creates new opportunities for analysing the development of the market for bio-based materials, as well as how they contribute to achieving sustainable goals.

Acknowledgements

The activities on which this paper is based are financed through the H2020 project BioMonitor (Grant Agreement No N°773297). Further information on the project is available at: https://biomonitor.eu/.

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