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Information behaviour of farmers, foresters, and advisors in the context of digitalisation in the EU

This paper provides insights into the information behaviour of European farmers, foresters, and advisors in the context of the ongoing digital transformation. Data collection and analysis for this study were carried out as part of a substantial innovation project to create a new online knowledge platform, called EU FarmBook, for primary sector practitioners. Besides informing the design and development of this user-centred platform, this study also provides useful inputs to better understand the perceived information needs, preferences, and information behaviour of primary sector practitioners, which is an underexplored area of Agricultural Knowledge and Innovation Systems (AKIS) in Europe. This paper presents and draws on 40 semi-structured interviews conducted with farmers, foresters, and advisors from 20 different countries. The results reveal some of the major ways in which the rapid advancements in digital information and communication technologies have affected farmers, foresters, and advisors. The problem-solving strategies of primary sector practitioners now rely largely on online resources. Searches for photos and videos have become a particularly integral activity that reflects their practice-oriented and solve-it-yourself attitudes. This has implications for agricultural extension services, which must be prepared for the challenges and changes that the digital revolution will bring to extension work.

Keywords: Digitalisation, Interviews, EU FarmBook, AKIS, Extension Services.

JEL classifications: Q12, Q16

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Introduction

The context of primary sector production has never been more challenging than it is currently. There is a multi-dimensional set of concerns in relation to demographic change, climate change and globalisation. On top of that, the outbreak of the COVID-19 pandemic in early 2020 and the 2022 war in Ukraine brought additional and unprecedented (ongoing) challenges, emphasising the underlying weaknesses of food systems as well as the vulnerabilities of those working across agri-food value chains (Aday and Aday, 2020; Parks *et al.,* 2020).

This challenging context is driven by another factor: the advancement of information and communication technologies. In agricultural and food systems, digitalisation is one of the most trending transformations. The emergence of this transformation is well reflected in the growing interest expressed in various academic (Burg *et al.,* 2019; Bilali and Allahyari, 2018; Rolandi *et al.,* 2021; Rijswijk *et al.,* 2021; Rose *et al.,* 2016) and policy circles (European Commission 2020; Lajoie-O'Malley *et al.,* 2020; European Commission, 2016). With robotics, sensors, and big data analytics, producers' decision-making process can shift from relying on traditional or experimental knowledge to a management that is "*highly optimized, individualized, real-time, hyper-connected, and data-driven"* (Ingram and Maye, 2020, p2.). Digital technologies aim to increase agricultural productivity in a way that reduces environmental impacts and manual labour while still satisfying consumers' needs to improve the way the food system works. Digitalisation is therefore also seen as a key contributor to the transition towards sustainable food production (Bilali and Allahyari, 2018).

Beyond the production-related applications of digital technologies, the rapid advancement of information and communication technologies has brought about fundamental changes in people's knowledge and information behaviour as well (Chowdhury and Chowdhury, 2011). These changes have been driven by a never-before-seen level of connectivity that characterises people's information environments (Eurostat, 2020). Connections have never been so easy to make and maintain due to the emergence of information communication technology (ICT) solutions. These include various digital platforms, social networking and content-sharing sites, search engines and easily accessible high-speed internet (European Commission, 2020). Within that perspective, there is relatively little known about the information behaviour of European farmers, foresters, and advisors. However, it has been evidenced that the ways of seeking, exchanging, and using information and knowledge in agriculture, forestry, and extension services play a major role in adapting to the major challenges that agricultural and food systems are currently facing (Klerkx *et al.,* 2019; Rijswijk *et al.,* 2021; Lajoie-O'Malley *et al.,* 2020; Klerkx, 2021; 2020). This research gap is particularly noteworthy given the enormous efforts that have been made to conceptualise and institutionalise formal and informal Agricultural Knowledge and Innovation Systems (AKISs) in EU member states (Knierim *et al.,* 2015).

The concept of AKIS is a good example of a systems-thinking approach involving the disciplines of sociology, agricultural extension, and information sciences to understand the process of knowledge production and exchange, learning, and innovation in agriculture. At the time of its inception, the 'Agricultural Knowledge Systems' (AKS) was understood as linear knowledge transfer structures coordinated at nation-state levels (Leeuwis, 2004). Later, this approach gradually evolved into a multi-stakeholder system that shifted the focus to collaborative research of knowledge and information structures and included farmers and other support services. Agricultural Knowledge and Innovation Systems today acknowledge that knowledge and innovation transfer is fragmented and characterised by pluralism and diversity due to the numerous types of networks and interactions through which information and knowledge flow (Sutherland *et al.,* 2017; Knierim *et al.,* 2015).

In the context of AKIS, information and communication technologies are now seen as pivotal tools with great potential for fostering innovation in agriculture and related sectors. The use of various platforms for communication and content sharing can further stimulate multi-actor innovation activities through informal and formal networks. Although ICTs clearly have the potential to contribute to the removal of barriers to innovation, they contain certain elements that may hinder this process. Areas of concern are evidenced by the lack of use of social media in agricultural context, the lack or prohibitive cost of a reliable broadband internet connection in poor or remote areas, the generational gap in use of these technologies, the risk of information overload and misinformation, and the lack of maintenance of collaborative networks beyond project periods. This array of difficulties must be overcome by joint research efforts (EU SCAR, 2015).

These issues have been widely explored in the literature. In the interpretation of Fielke *et al.,* (2020), the potential implications of digitalisation for agriculture and extension services are to make knowledge and knowledge networks more connected and transparent. This suggests that more technology-mediated interactions will be made between farmers, advisors, and consumers. Klerkx *et al.* (2019) pointed out that scientific literature on digital agriculture is focused on either technical, natural, or design aspects of the application of these technologies in primary production, and tends to neglect the equally important social science aspect. Their interpretation suggests that digitalisation is likely to affect farmers' knowledge exchange through new modes of interaction. The concept of socio-cyber-physical takes this interpretation further when proposing an analytical approach to understand the interactions between social, cyber, and physical domains.

More specifically, interactions between cyber and social domains look at such an emerging issue that explores advisors' changing role in extension services at times when a vast amount of information is largely available to a wide range of users (Rijswijk *et al.,* 2021). This is also related to the negative impacts of digitalisation that often appear in the social sustainability context when social, economic, racial, and skill inequities lead to more highly skilled agricultural professionals displacing those with less training and digital skills (Rotz *et al.,* 2019; Carolan, 2020; Prause, 2021). This is expected to bring major changes and a resulting need for adaptation in the role of advisers as well. Eastwood *et al.* (2019) found that future advisors would rather spend their time helping farmers understand the value of data-driven farming technologies than promoting new technologies. The interface of social and cyber domains also encompasses the longstanding discourse on the so-called "digital divide". Several comprehensive studies highlight that poor ICT infrastructure, scarce skills in digital communication technologies, and certain determining sociodemographic factors present cumulative causalities that hinder rural development initiatives (Philip *et al.,* 2017; Farrington *et al.,* 2015; Trendov *et al.,* 2019; Salemink *et al.,* 2017; Cowie *et al.,* 2020; Haefner and Sternberg, 2020).

Agricultural Knowledge and Innovation Systems involve dynamic interactions between multiple actors that communicate, exchange knowledge, co-create innovations, and share best practices for farmers, foresters, and other rural businesses. In this complex ecosystem, the means of interactions constantly evolve, which inevitably affects the activities and information-seeking behaviour of farmers, foresters, and advisors. Adapting to this constant evolution is both a challenge for individuals with various backgrounds and a prerequisite to being an efficient professional in the digital era. A good understanding of practitioners' information needs and information retrieval is seen as an essential element in the development of AKIS that enhance users' access to reliable sources of knowledge and innovations. Although attempts to understand subfields of information behaviour have been made, such as in relation to internet use (Janc *et al.,* 2019), on-farm demonstrations (Sutherland and Marchand, 2021), use of mobile technologies (Baumüller, 2018; Bonke *et al.,* 2018; Michels *et al.,* 2020; Inwood and Dale, 2019), farm advisory services (Eastwood *et al.,* 2019; Rust *et al.,* 2022), and social media use (Mills *et al.,* 2019), exploring practitioners' information and knowledge journeys using the analytical framework provided by the information behaviour discipline has not yet been part of the AKIS literature.

The scope of this study

This paper aims to provide explorative insights into the information-seeking behaviour of European farmers, foresters, and advisors in the context of digital transformation. The framework of this study is provided by a Horizon 2020 Research and Innovation Action project. This EU-funded project aimed to assess the feasibility of and further develop the EU FarmBook digital knowledge platform. This interactive knowledge reservoir acts as an open-source e-platform, aiming to accelerate knowledge exchange and sharing of results generated by multi-actor projects and Operational Groups under the past H2020 and current/future Horizon Europe work programmes and the Rural Development Programme. Therefore, this digital initiative is strongly linked to the evolution of the AKIS ecosystem.

Building such an e-platform requires combined expertise and complex methodology. To ensure that the EU FarmBook

digital knowledge platform is fit for purpose, the platform was developed using a service design thinking approach. Through this approach, the EUREKA project thoroughly studied potential users' information needs, preferred channels of communication, as well as challenges faced in finding the most useful knowledge or information (Bull *et al.,* 2022). EUREKA provided a unique opportunity to engage diverse groups of professionals to gain a first-hand understanding of how they perceive their activities in the digital information environment. These examinations provided essential inputs into the development of the EU FarmBook in the first place, but they also produced rich empirical findings on how these professionals seek and use information in their day-to-day lives.

This paper presents explorative insights into European farmers, foresters and advisors' information seeking behaviour and consumption practices in the context of digital transformation. In the following sections of this paper, we first provide the theoretical framework of this study, including a description of information behaviour as a scientific discipline and exploration of information seeking behaviour through users' problem-solving practices. The theoretical framework is followed by the methodological framework, where we explain how this framework was operationalised in the EUREKA project and how the data collected has been analysed for the research described in this paper. This is followed by a presentation of the findings of 40 semi-structured interviews conducted with farmers, foresters, and advisors from 20 different countries. Findings highlight that the problem-solving strategies of primary sector practitioners now rely largely on online resources. Finally, we discuss the key implications for developing future mechanisms and instruments for knowledge transfer, specifically the design of the EU FarmBook.

Theoretical framework

Information behaviour research is founded on the fact that seeking information is one of the most fundamental human activities. Information behaviour research offers a holistic approach that aims to explore people's relationships with information and knowledge while focusing on mediums, sources, and circumstances of encountering (Case, 2007). Following from this, Ford (2015) presents information behaviour as Wilson's (1999) nested concept: The core activity is a search for information using a certain tool (e.g. search engine, social networks); this search, along with other activities such as browsing or monitoring, forms a personal info-seeking strategy. This strategy is the foundation of information behaviour (Ford, 2015).

Information behaviour research started with studies on library use and scientists' information sources (Wilson, 2000). Later, the interest shifted towards what types of information sources are used by individuals, groups, organisations, and communities, and what constitutes their information behaviour (Ford, 2015). Most recent enquiries acknowledge that information behaviour activities are in a constant state of change, partly because of the rapidly changing technologies and the very diverse circumstances of individual users (Bawden and Robinson, 2011). Referring to the extent of change in the focus of recent enquiries towards the advancement of digital and online solutions, Chowdhury and Chowdhury call for a paradigm shift in information behaviour (Chowdhury and Chowdhury, 2011).

This consequential shift is explored in various recent statistics and findings. In 2019, accessing the internet on a daily basis was an ordinary activity for more than three-quarters of individuals in the EU (Eurostat, 2020). Going online is not just a routine step for most people due to the advancement of mobile and portable devices, but these technologies also keep users in continuous contact with information sources, essentially making information seeking a continuous activity (Burford and Park, 2014; Nicholas *et al.,* 2004). Smart applications can help filter online information by letting in information only from selected domains that fulfil individuals' information needs (Burford and Park, 2014). Today, a substantial fraction of information that is shared flows through social media sites thanks to the 3.5 billion people who use these platforms as part of their communication, news acquisition, cultural consumption, socialisation, and professional activities (Muhlmeyer and Agarwal, 2021). The constant flow of information has accelerated information consumption, which has significantly reduced users' tolerable waiting duration when seeking information (Nah, 2004). 'Information overload' has been described as a phenomenon in which a user receives too much uncontrolled or unfiltered information that essentially leads to a sense of frustration, stress, and in some cases depression (Muhlmeyer and Agarwal, 2021; Fuchs, 2014; Matthes *et al.,* 2020; Bright *et al.,* 2015; Dijck, 2013). This has clear implications for most work in today's economy as well, as a large amount of available information increases the complexity of information-seeking activities (Chowdhury and Chowdhury, 2011). Another important consequence of multiple digital sources, tools, and applications is the complication of users making sound credibility judgements about online information. In addition to the established authority and expertise of the creator, users consider accuracy, recency, reliability, trustworthiness, and truthfulness to underlie credibility judgements (Rieh *et al.,* 2010). However, detecting when online content is fake and/or intended to mislead has never been more challenging due to the sheer growth of information shared and communicated online (Zhang *et al.,* 2020).

The theoretical framework used in this work is rooted in two concepts. First, it relies on Ford's (Ford, 2015) conception of information behaviour that identifies five constituent activities. As a starting point, (i) *perceiving some information-related needs* involves thinking of needed and not needed information; (ii) *coming into contact with information potentially relevant to some needs* covers activities such as searching, browsing, and monitoring information, as long as the information encountered carries some relevance to the person; (iii) *assessing the suitability of information in relation to some information-related needs* includes key steps in information behaviour such as judging intelligibility, relevance, trustworthiness, and usefulness; (iv) *using information* covers recalling, applying, sharing, or communicating information; finally, (v) *organising information for one's own access and use* is related to individuals' classification

and cataloguing of information (Ford, 2015). This approach has provided points of reference for identifying the aspects of respondents' information behaviour.

A second key element of the theoretical framework was the inclusion of an empirical approach centred on the problem-solving practises of users. In the EUREKA project, a key objective was to gain a sufficient understanding of the information needs, preferred channels, and challenges of potential users of the EU FarmBook to ensure that the platform is designed to satisfy their needs. The problem-solving approach was chosen based on the generally held view that problems and problem-solving are primary reasons for individuals to engage in information-seeking activities. This problem-specific aspect has been discussed thoroughly in information behaviour literature. According to Belkin, "*When people engage in information-seeking behavior, it's usually because they are hoping to resolve some problem, or achieve some goal, for which their current state of knowledge is inadequate*" (Belkin, 2000, p58). The problem-resolution chain model proposed by Wilson (1999) became influential in information behaviour research. The starting point for his model is a problem or situation that presents a certain state of uncertainty. The model identifies problem identification, problem definition, problem resolution, and solution statement as key stages in information seeking and suggests that uncertainty decreases the further the information seeker moves along the chain. However, it was later acknowledged that moving to a solution statement may require successive searching behaviour that is identified as a fundamental aspect of information-seeking behaviour (Spink *et al.,* 2002).

Chowdhury *et al.* (2011) claim that the complexity of the digital information environment may further increase individuals' sense of uncertainty at any stage of the search process. E.g., choosing channels and sources, trying to remain up-to-date in the field, formulating a search expression, information overload or out-of-date search results (Nicholas *et al.,* 2004). Belkin (2000) looks at information-seeking behaviour from an information system perspective by drawing attention to the importance of query formulation as the primary representation of an individuals' information problem. Savolainen's (2008) study uses the critical incident interview technique to assess source preferences in the context of seeking problem-specific information for non-work purposes. It was revealed that problem-specific information is sought through human and networked sources in the first place, while printed sources came as sources of supplementary information in the process of information-seeking. In terms of criteria for the selection of sources, availability and accessibility were prioritised over usability, which may refer to the element of urgency in problem-specific information seeking. However, Case (2007) argues that because information seeking involves a series of situations, motivations, and surroundings, it implies the influence of various factors that do not necessarily lead to rational or uniform information-seeking behaviour. This is a characteristic of human information behaviour that any research undertaking to explore this subject must consider when methodological approaches are being developed.

The above examples have illustrated the diversity that characterises information behaviour research from a problem-specific perspective. In the context of this study, this problem-oriented approach was adopted to explore and identify the typical elements and patterns that constitute the information-seeking behaviour of primary sector practitioners. The next section will present how this approach was applied as part of the methodological framework of the EUREKA project.

Material and methods

As indicated above, this paper presents the information-seeking behaviour of European farmers, foresters and advisors by drawing on a specific segment of the mixed methodology designed to categorise potential users of the EU FarmBook knowledge platform into user personas'. The categorisation of these agricultural personas was an essential element in the development of the FarmBook because it supported the integration of the user perspective in the design of the platform (Bull *et al.,* 2022). The mixed methodology used to provide a sufficient grounding for the development of these user personas included an initial user-profiling workshop, four EU macro-region workshops, one quantitative survey, qualitative interviews, and a final validation workshop. The 40 semi-structured interviews made with farmers, foresters and advisors from 20 different European countries comprise the data presented and analysed in this study.

Semi-structured interviews are an often-used tool for qualitative data collection in social science because this type of interview can be easily adapted for various study purposes (Brinkmann, 2014). Semi-structured interviews were particularly suited in this case because the target group of this study represented a diverse community, and an approach allowing flexibility came as a great advantage when interviewing professionals with different backgrounds (King *et al.,* 2019). This advantage was multiplied when social-distancing rules and lockdowns were implemented across Europe and the rest of the world due to the COVID-19 pandemic. Following these interventions, the interviews had to take place in online environments using various communication platforms.

The interview guideline[1] was centred around four major themes. The identification and definition of these themes were based on, online regional workshops with potential users, and the incorporation of concepts from information behaviour research. The first theme covered fundamental aspects of users' information behaviour by addressing their *routinely used information sources, tools, and information retrieval pathways*. The second theme on the *use of digital tools or sources for professional purposes* was covered by users' narratives in which they recall an occurrence when professional problems were solved by using knowledge or information found through a digital tool or source. The theme of *an ideal online platform for users* directly served the development of the EU FarmBook with essential user perspectives on the desired features of an ideal digital information system. The fourth theme concentrated on specific *socio-demographic information* because these factors have been shown to play an explanatory role in users' information behaviour.

[1] The interview guide is available on request from the authors (kiraly.gabor@aki.gov.hu).

Interviewing was supported project-wide to ensure that interviewers carried out the interviews in a uniform way. This support included a one-day online training for interviewers with specific emphasis on preparation (sampling, invitation and collecting consent), interviewing, post-production (transcription and translation), and a follow-up workshop to share experiences and feedback in relation to the ongoing interviews. The sampling of interviewees was subject to non-probability purposive expert sampling, meaning that there are no probability-related preconditions involved. However, sampling is based on deliberate choices due to knowledge, experience, and proficiency associated with potential participants willing to provide information (Etikan *et al.,* 2016). In that sense, interviews were selected and asked for participation based on the project partners' judgement.

The interviews were conducted over a period of five weeks from the end of April to the beginning of June 2020. Due to COVID-19 restrictions, each interview was conducted either by phone, Skype or Zoom. In the majority of cases, the interviews were conducted in the mother tongue of the interviewee, which ensured that they could express themselves as freely as possible and without language constraints. All participants were informed about the research prior to giving their free written consent to participate. Each interview was recorded, transcribed, and translated into English.

Verbatim English transcriptions of the interviews were thoroughly analysed using a qualitative content analysis facilitated by the software QDA Miner Lite® (Silverman, 2020). Qualitative content analysis is a flexible method for analysing text data. Hsieh and Shannon define qualitative content analysis as *"a research method for the subjective interpretation of the content of text data through systematic classification process of coding and identifying themes or patterns*" (Hsieh and Shannon, 2005, p1278). The key element of qualitative content analysis is the coding process. The aim of this highly iterative, intuitive, and reflexive process is to expand and interpret the meaning of the raw textual data in the framework of careful and consecutive examinations (Silverman, 2020; King *et al.,* 2019). The coding process defined codes inductively, meaning that there was no pre-defined coding scheme used. Codes were defined purely based on empirical materials. This step was followed by the iterative course of categorisation, re-coding, and interpretation (Corbin and Strauss, 2015).

The final sample provided a unique opportunity to gain insights into elements of information behaviour in European agricultural society. In total, 40 interviews were conducted, of which 37.5% (15) were with farmers, 32.5% (13) with farm advisors, 17.5% (7) with foresters, and 12.5% (5) with forestry advisors. The interviews covered 20 different countries in four predefined regions. The vast majority of interviews were conducted with male participants. No female participants from the Atlantic-North Sea region were involved in the interviewing. In terms of age distribution, most participants were aged 55 or younger, with less than 18% of participants in the oldest age group. Table 1 shows the detailed distribution of the sample.

Results

The most essential findings of this study are the identification of activities that are understood in this context as core constituents of information behaviour based on Ford's (Ford, 2015) analytical framework. This section gives a brief description of these findings in the form of descriptive statistics derived from incidences and representative quotations (See Table 2).

Searching online was one of the most common activities described by participants, with 83% (n=33) reporting that web search is part of their problem-solving approach. However, there was a difference in distribution between the three target groups, with 95% of the advisors (n=18) reporting this activity but only 36% (n=4) of the foresters mentioning web search as part of their information-seeking practices. In the farmers' group, nearly 80% (n=15) of participants mentioned this activity. Web searches can be distinguished into three groups. These are navigational, informational, and transactional searches. The navigational search usually targets one particular website. The purpose of an informational search is to satisfy information needs by learning about target content. In transactional search, the aim is to interact with the target content, for instance through online shopping, accessing datasets, or downloading content (Broder, 2002; Jansen *et al.,* 2008). This classification was clearly reflected during the analysis of the participants' interviews. Participants' navigational searches often target websites that are visited on a routine basis. These sites are usually official channels, that either collect and share information relevant to a specific sector or locality or generate information. These sites are operated by EU or national bodies, universities, and scientific organisations. Newsletters are also considered a navigational search as subscribing is a deliberate user decision for which participants expect in return regular updates concerning a chosen activity from a source of interest.

Table 1: Composition of sample for interviews.

Region	Countries represented	Profile			Gender		Age		
		farmer	forester	advisor	male	female	-35	35-55	55-
Danube - Balkan	HU, SK, BG, RO	5	1	4	9	1	3	6	1
Atlantic - North Sea	BE, FR, UK, NL, DE	4	2	4	10	0	4	3	3
Nordic - Baltic	EE, FI, LV, LT, PL, SE	2	4	4	6	4	2	7	1
Mediterranean	IT, EL, MT, PT, ES	4	0	6	9	1	3	5	2
TOTAL	20	15	7	18	34	6	12	21	7

Source: Own composition

Table 2: Constituent activities in participants' information behaviour.

Information behaviour activity	Frequency	Representative quotation
web search	83% (n=33)	"*There is no longer something that cannot be found on the digital interface, whatever cannot be found. The question is more about how to navigate*." (58 years old farmer from Slovakia)
searching for pictures, images, photos online	45% (n=18)	"*When I get pictures from the field to identify something, I use online images to provide an answer. Look, I recognise weeds, but farmers, for example, very often do not know weeds in the stages of the germ leaves or in the first stages of the native leaves. They don't even recognise rye flowers, which are quite different than blooming*." (47 years old farmer advisor from Estonia)
searching for video-based online information	58% (n=23)	"*Sometimes it's good when you when you see things. So if you can get a clear video of what they are doing and what is happening, that's quite useful. But that's not always available. So you always have to always have to go and look for some written text*." (29 years old farmer advisor, from the Netherlands)
engaging in social media	65% (n=23)	*"Coming back to Facebook, it depends on the nature of the group. Does the group have a good host? For example, there is a group for young farmers, it has 7000 members and I know the guy who created it and is patronising it. There is relevant information coming and going and relevant information being exchanged. (…) If there is moderation, from someone who knows what they are doing and people who might be able to steer it even outside the moderator, then it can work." (35 years old farmer from Hungary)*
smart applications	70% (n=28)	*"Well, from my experience, there is a quite numerous of inspiring applications that have been introduced over the recent years in the primary sectors. Let's say from precision farming to precision irrigation to application for weather forecasts"* (40 years old farmer advisor from Italy)
peer-to-peer information flow	85% (n=34)	"*Sometimes it's easier to call a colleague than search for a solution on the Internet, especially in the situation which is very critical."* (50 years old farmer advisor from Lithuania)
accessing printed materials	80% (n=32)	"*Books, I used to, but no, I don't get the time now to read the new books. Maybe the latest one was about agroecology. But I have to refresh some knowledge that I've had before. No if we talk about offline, it is mainly newspapers and magazines. But then I get often some bit of information here and there. And then I complete it with more online actual information."* (45 years old advisor from Romania)

Source: Own composition

Informational searches follow consecutive click-throughs, keyword-based searches, or a combination of these. Participants' search intents are linked to learning more about specific topics such as pests, diseases, equipment, or nutrients. Market price information is also often sought by farmers and foresters to make sure they are well informed before making any deals that involve selling their products. Another typical reason for informational searching is tender or proposal writing for funds and development support. This is mostly related to advisors. Transactional searches usually target equipment shopping, use of satellite map images, and weather databases.

Image-based searches have also become a very important feature of online search activities. Many participants reported that they often search for photos and images specifically when they need to find information quickly. The significance of images in participants' information-seeking practices was strongly reflected in the interviews, with 45% (n=18) of the participants mentioning using this approach. These practices included several types of visual elements in various contexts: searching images, sending or posting images, learning from or demonstrating with illustrations, monitoring crops from satellite or aerial images, or detecting or assessing relevant characteristics of subjects of interest, such as weed detection.

Online videos were even more prominent in participants' information and knowledge seeking and consumption behaviour, with 58% (n=23) sharing experiences of coming into contact with online videos. Participants shared that they searched for videos related to their interests on a regular basis. This was true across the three main potential user groups of the EU FarmBook (foresters, farmers, and advisors). These activities appeared in contexts related to learning about technologies or farming practices. A significant share of the participants, mostly advisors, said that they used this format as a tool for demonstration in their advisory work.

Social media use clearly has a growing influence on people's information behaviour. Social media-related activities were mentioned by 65% (n=23) of the participants. This includes Facebook, Twitter, LinkedIn, Instagram, and WhatsApp. However, individual views on social media presented a mixed picture, ranging from regular and willing users to those who completely reject use of these platforms.

The multi-functionality of smartphones drives the use of numerous smart applications that aim to serve the immediate needs of farmers, foresters, and advisors. Seventy percent (70%, n=28) of the participants mentioned that they regularly use smart applications in a professional context. Findings show that these apps serve a wide range of functions such as communication, weather forecasting, plant protection and pesticide control, farm management, mapping volume calculations, and access to satellite imagery. The importance of mapping applications can be further emphasised in the

context of forestry, wherein these tools appear to be must-have assets for forestry professionals with reliable data, navigation, and locating functions.

Interviewees also often reported information searching activities that do not take place online. Requesting information through peer-to-peer interactions was referred to as the most generic offline information-seeking activity. In-person interactions were part of the information behaviour of participants in many forms, including direct face-to-face interactions, various types of meetings, forums, presentations, and events where it is possible to meet physically. These encounters seem to be excellent opportunities for peer-to-peer information exchange, which the target group approached in the study view as particularly needed: 85% (n=34) participants mentioned that they needed this form of information.

Printed materials were identified as another major source of information for the participants. Although the declining importance of these formats has been a long-standing trend in information behaviour studies, the targeted professionals in this study showed a pronounced interest in printed materials such as professional magazines, journals, and periodicals, or books. These sources of information were mentioned in 80% (n=32) of the interviews. Despite the shrinking space for printed farming press, these sources seem to remain important reference points in participants' information behaviour. Many participants specifically named such sources, suggesting that they use them on a regular basis. In terms of access, subscriptions seemed to be a common solution. Subscriptions are typically associated with workplaces (institutions or organisations) or memberships, which ensure permanent access to these sources. Subscriptions, whether paid or free, often provide the latest issues of journals and magazines in electronic format. Although this delivery method makes these contents convenient to consume, it also links this activity to the internet, which inevitably leads to more online presence and web searches.

Discussion

The thematic content analysis resulted in the identification of several activities that constitute practitioners' information behaviour. Activities were assessed using Ford's conception of information behaviour (Ford, 2015) and a problem-solving approach. In that sense, respondents shared their typical procedure when confronted with a constant stream of information in problem-solving situations.

Although Ford's framework includes five components of information behaviour (see Theoretical Framework), this study did not identify all of these. Respondents provided in-depth descriptions of how they *come into contact with* various forms of information after *perceiving certain needs that relate to information*. In the methodological setting of this study, this need was artificially presented via concrete questions concerning their professional problem-solving experiences. Given the ease of access to what was often referred to as an "overloading stream of information", it is not surprising that interviewees frequently reflected on how they *assess the suitability of information*. According to Ford's interpretation, *using information* encompasses recalling, applying, sharing, and communicating it. These types of activities were clearly demonstrated in multiple interview cases. However, *classification and cataloguing of information*, the fifth component of information behaviour in Ford's framework, was not discussed in the interviews, thus this area remains unexplored in this study.

From a general perspective, information behaviour activities are usually arranged into two basic information retrieval pathways that participants take in their everyday operations. An information pathway is an individual's journey of selecting various information sources over time to attempt to overcome a problem or a problematic situation (Savolainen, 2008). The first type of information search is one that is triggered by the need for a quick solution, response, or fix to smaller or less complex day-to-day questions or problem, typically implemented on the ground and on a single device (in the case of online searches). The second is a more complex process involving multiple searches and requiring more time, due to a question or issue of a more complex nature. These multi-step searches usually require the use of multiple resources and tools. Multi-step information retrievals can begin as quick searches that do not yield the desired answer or solution, and thus drive individuals to engage in multiple and successive information behaviour activities. These more complex problems and the associated multi-step, multi-source information retrieval pathways resonates with the general concept of AKIS, which builds on diversity and pluralism in information and knowledge transfers within primary sectors. The effectiveness of AKIS can be improved if the design of the related activities considers the findings of this study, principally that the information behaviours of primary sector practitioners involve a diverse combination of several equally important sources and tools.

An important finding of this study is that image-based searches have become an important part of practitioners' information-seeking approaches, particularly among advisors, thanks to the powerful internet search engines that make this functionality readily accessible. Recent studies have shown that the characteristics of online image searches differ from general online searches. Image search is usually driven by exploratory motivations and conducted with shorter queries (Xie *et al.,* 2018). Participants prefer images over text-based results because images enable visual information processing that leads to quicker information acquisition. Additionally, an image search often serves as the entry point for a subsequent web search if finding the appropriate image generates a click-through to the host website.

Although no comprehensive theory has yet been developed to understand people's intentions and behaviour concerning viewing of online videos, it seems likely that the magnitude of online video consumption for learning, development, and information has caught up with videos made for entertainment. This is evidenced by the fact that so-called "how-to" videos have become one of the most widely viewed online video types (Purcariu, 2019). Many participants reported that they routinely turn to YouTube – the largest and most popular video-sharing site – for information. The motivation or intent of these video searches is to seek information on technologies, practices, or innovations of interest. Interviews suggest that participants seek both professional

and amateur content. Searching for images and videos also points to the fact that participants' work is highly practice-oriented. An important consequence of this is that they often try to solve problems and issues themselves, and visual materials can undoubtedly be very helpful in this respect.

The prominence of social media in participants' information behaviour is not surprising given the role that these platforms have had in everyday life. Participants' reflections on social media use fully supported Klerkx's statement claiming that farmers and advisors actively use social media platforms (Klerkx, 2021). Themes related to farmers' and advisors' use of social media are beginning to be explored in other studies. However, various topics have been recommended to be on the research agenda of agricultural and extension services (Klerkx, 2020). What has been found thus far is that practitioners are actively using these networks, mostly for knowledge sharing and learning, and more rarely for knowledge generation (Rust *et al.,* 2022; Klerkx, 2021; Mills *et al.,* 2019). However, there is a growing number of examples of content and influence generation in the context of agriculture and food facilitated by various social media platforms (Klerkx, 2021).

Reports made in the interviews were in line with these findings, emphasising that social media platforms are now a primary source in practitioners' information behaviour, including among farmers. These platforms have become useful virtual spaces for professional socialisation, including through the formation of groups centred around certain topics, themes, or interests. However, if such groups lack professional moderation, there is higher risk of the disseminating and trending of misleading information that may discourage people from further use of these forums.

Social media platforms provide an easy and reliable way to maintain client contacts even in times when social distancing measures are in place. Many participants identified Facebook as an important source of information, which is most likely due to the News Feed feature and its customisable preferences. Most of the negative remarks made by interviewees on social media mentioned its time-consuming nature and frustration resulting from encountering misleading or false information.

Many studies have investigated farmers' use of smartphone applications (Bonke *et al.,* 2018; Inwood and Dale, 2019; Michels *et al.,* 2019; Rose *et al.,* 2016; Baumüller, 2018). The interviews showed, in line with these previous studies, that more and more applications are becoming available for agricultural and forestry purposes. However, there is still great potential for growth in their adoption. These decision-support tools are particularly useful in *ad hoc* problem situations that often occur on the ground. Quick access to information, provided a network is available, is a highly valuable feature in remote forest areas. For foresters, maps are a very important form of information, which is traditionally used in paper form, and older generations seem reluctant to change this. However, the younger generation shows openness to digital maps accessed on a smartphone or a tablet. The future role of paper maps has been questioned due to the increasing availability of mapping applications, but it seems that paper maps still have qualities that make this format relevant in the digital age (Hurst and Clough, 2013).

Despite all the advancements in communication and access to information made possible in the digital age, peer-to-peer information flow is still an integral part of primary sector practitioners' information behaviour. This activity was reported so frequently by participants that it clearly supports the often-evidenced finding that farmers' number one source of information is other farmers (Garforth *et al.,* 2003; Kilpatrick and Johns, 2003; Šūmane *et al.,* 2018). Philips *et al.* (2018) explain this behaviour with the principle of homophily, claiming that farmers prefer farmers over other sources. Such peer-to-peer interactions usually involve information exchange or requesting advice. The latter was reported to be most common in cases when an information search was driven by encountering or considering a previously non-experienced practice, technology, or disease. The existence of trust in these information exchanges is based on three main factors: a long-standing acquaintance or partnership, knowledge of having experience in the issue, and being in a position of authority, such as an advisor or veterinarian. These findings related to personal contacts support the importance of understanding the socio-organisational context of farming (Klerkx *et al.,* 2019; Rijswijk *et al.,* 2021).

Alongside peer-to-peer information flows, the interviews demonstrated that printed materials still constitute a major information source, which is in line with those studies that highlighted the importance of access to explicit knowledge in printed materials. Collectively, these results show that printed materials still have the capacity to support routine professional activities such as solving problems, staying up-to-date on the latest news, or spreading sector-specific information, despite the rise of the Internet (Gava *et al.,* 2017; Klerkx and Proctor, 2013; Kutter *et al.,* 2011). However, this capacity has been on a downward trend in terms of their share in participants' information behaviour, which makes their role in the future uncertain (Rust *et al.,* 2022).

The thematic content analysis also revealed some overarching themes that point to the changing nature of agricultural and forestry advisory work in the context of emerging digital information technologies in these sectors. One of these themes is that participants are increasingly concerned about the reliability of the information they find online. According to Ford (2015), this information activity assesses or judges the suitability of the information, which is in essence a judgement of how intelligible, relevant, trustworthy or useful the information the individual comes into contact with is. This was expressed frequently in the interviews, making this issue a common ground for participants regardless of their personal or professional background. Participants shared their experiences of situations when they found it difficult to decide what was reliable, trustworthy, or validated versus what was not among the wealth of information available. Questioning the reliability of these sources is usually driven by the perception of non-professional content, underlying marketing or advertising objectives, or out-of-date information. Some participants reported that they cope with this issue by examining two things: the structure or appearance of websites and the references (or lack thereof). These factors are in line with those findings from information technology research that have shown links between website-related factors and online trust (Kim and Lee, 2020).

Another interesting overarching theme is related to the changing nature of extension services. Traditionally, extension

services are inherently based on in-person encounters and meetings in agriculture and forestry (Klerkx *et al.,* 2019). Eastwood (2019) explored advisors' sensemaking role in assisting farmers in the use of data-driven technologies, while Ayre (2019) demonstrated the challenges and possible solutions for advisors to develop their services to meet the growing information and knowledge needs of farmers. Such a challenge is explored by Rijswijk (2019), who demonstrates that digitalisation responses of agricultural knowledge providers are often *ad hoc* in nature, highlighting the lack of a strategic approach as well as suggesting uncertainty towards digital transition in agriculture. Based on Ingram and Maye's review (2020), this may lead advisory and extension services to face the emergence of demands for developing new capabilities, practices and skills. In particular, the latter statement was reflected in the interviews: advisors in the sample of this study seemed to agree that one of the essential features of advisory work is the possession of thorough and up-to-date knowledge of their field. In their information behaviour, sources included online, printed, and in-person contacts. Trustworthiness of information was an issue of particular importance to advisors, which can be explained by the fact that they are accountable for the knowledge they pass on to their clients. It is therefore worth noting that the free flow of information available online may lead to a situation where advisors will need to compete with the numerous online information sources, further questioning the traditional linear extension models. This might become particularly important as farmers become even more keen to follow online opinion leaders or influencers (Rust *et al.,* 2022).

References to the importance of communication were also a common element in the interviews. These statements clearly indicated the fundamental role of communication in advisors' activities. These reports also revealed that a form of hybrid online-physical communication has started to appear in advisors' communication toolbox. Social distancing measures induced by the pandemic clearly contributed to this trend, as they necessitated staying in touch and continuing advisory work virtually with the use of the various ICT tools.

Conclusions

This study revealed explorative insights into the information-seeking behaviour of European farmers, foresters and advisors, drawing on 40 semi-structured interviews practitioners from 20 different countries. Data collection and analysis for this study were carried out as part of a large Horizon 2020 innovation project to create a new online knowledge platform for primary sector practitioners. In the development of this 'EU FarmBook', the categorisation of agricultural personas and future potential users of the platform was an essential element.

This task of the development work was specifically designed to assess how farmers, foresters, and advisors search for, use, or exchange information in their everyday operations. In addition to being a particularly useful element of the platform development, this task provided highly useful input to better understanding a less explored area of Agricultural Knowledge and Innovation Systems in Europe. The rapid advancements in digital information and communication technologies directly and indirectly affect farmers, foresters, and advisors. A digitalised, empowered, and smart European agriculture can be built on a strong foundation of understanding these practitioners' information needs and how they can be met.

Clearly, the use of various ICTs forms a substantial part of the participants' work-related activities. The study showed that a significant proportion of online searches are now image-based as opposed to text-based. Photos and videos can often convey information faster and more efficiently, which is a key aspect both in a quick problem-specific search or a multi-step search. Farmers, foresters, and advisers are specifically practice-oriented. Therefore, there is a growing demand for high-quality images of farming practices, technology demonstrations, and video tutorials.

It is important to point out that practitioners' access to an almost unlimited amount of online information poses new challenges for advisors working in the field. They should be prepared to be able to use the latest ICT technologies in their advisory or demonstration activities and to expertly react to practitioners' information retrieval themselves. In that sense, the traditional linear extension model can no longer be maintained because there are many other sources, tools, platforms, and applications that will likely make future extension models more diverse and complex, like the information environment itself. This factor should be considered when developing future instruments for sharing and dissemination of knowledge and innovations. This study and the underlying exploratory work have not only contributed to the development of the EU FarmBook agriculture and forestry knowledge platform, but will also provide useful insights for the next phase of research on the information behaviour of European farmers, foresters and advisors.

The current study has some limitations that the authors wish to acknowledge. The most obvious limitation is the consequence of the purposive expert sampling procedure of the research. The sample used in the research does not statistically reflect the composition of the farmers, foresters and advisors in the countries concerned. However, Etikan *et al.* (2016) claims that studies adopting purposive sampling concentrate more on particular characteristics and expertise to be involved, rather than a cross section of various socio-demographic variables of the population.

Although the interviews conducted in mother tongues were seen as a technique that supported data collection for this study, the quality of English translations varied widely due to the use of online translation tools. Translated transcriptions in uneven stylistic qualities required considerable post-editing efforts and inevitably reduced the efficacy of content analysis.

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Embeddedness of Hungarian pig prices in the European pork market: a volatility spillover and partial wavelet coherence study

Compared to most of the agricultural commodity markets in the European Union (EU), the pig market is less regulated and EU pig prices can be regarded as free market prices. It is thus an ideal economic research opportunity to investigate agricultural market integration and spatial price transmission mechanisms in the EU in the different Member States (MS). Depending on the geographical location, the decoupling of production costs from prices paid to pig farmers can jeopardise the fragile market balance between producers and processors. To retrospectively identify price setting trends, this paper examines how price return trends in the Hungarian pig sector are reflected in dynamic Diebold–Yilmaz spillover indices between 2007 and 2021. The results show that Hungary was mostly a net spillover receiver throughout the investigated period. Pairwise comparison of price spillovers to and from other MSs indicated that the German pig market had the strongest effect on the price forecast error variance in the Hungarian market, but transient interaction with other MS markets was also detected. To obtain a detailed time domain representation of the multivariate relationship between different MS's price returns, our method considers an improved partial wavelet coherence (pwc) approach, which – to our knowledge – has not yet been used for analysing agricultural commodity prices. It was concluded that despite similarities, the German price and the EU average price affected the Hungarian market at distinct time scales. Collectively, our results indicate that the Hungarian pig producer prices underwent markedly different market regimes in the last decade due to shifting patterns of intra-European spatial connectedness of pig markets, which shall provide a reference for future modelling studies.

Keywords: Pig Producer Price, Price Transmission, Diebold–Yilmaz Spillover Index, Partial Wavelet Coherence.
JEL classifications: Q11, Q13

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Introduction

In the European Union, financial subsidies paid to producers of products which were not eligible for direct payments (e.g. fruits, vegetables, poultry, pork and processed products thereof; Brockmeier and Salamon, 2003) came under intense scrutiny during the series of trade talks under the umbrella of the Doha Development Round between 2001 and 2008. These negotiations marked the end of the 'protectionist' approach of the Common Agricultural Policy (CAP), which was considered back then as a vestige of trade logic from Cold War times. Nowadays, a private storage scheme for EU pork producers is offered by the European Commission, aiming to balance the pig market, provide hedging opportunities and stabilise pig prices under abnormal market conditions (EU regulation 1308/2013; Clop-Gallart *et al.,* 2021). In 2004, and then in 2007, 10+2 countries joined the European Union, where pig production had evolved very differently from the old MS's. As a result, structural differences between the pig industry of the old and new MS surfaced immediately (Baráth *et al.,* 2021; Utnik-Banaś, 2022). In this study, we take a retrospective look at how the Hungarian pig price evolved after this transition period.

Customarily, many of the Hungarian pig farms and slaughterhouses abstained from entering into long-term contractual commitments (Marczin *et al.,* 2020). Over the past few years this situation has changed, and today many of the major processors apply a pre-fixed price or a price formula based on the wholesale prices of valuable meat parts. The most popular contract for determining producer price has become the price formula based on the largest pig producer European countries. In parallel, cost-based pricing or performance-based incentives have almost disappeared in purchase agreements (unpublished results). Undoubtedly, these measures adversely affected producers' market positions in the long run. A questionnaire launched by the Hungarian Institute of Agricultural Economics (AKI) and the Association of Hungarian Pig Breeders and Pig Farmers (MSTSZ) in 2018 asked Hungarian pig farmers about their contractual relationships with slaughterhouses/processors (unpublished results). The survey indicated that the prevalence of trading on spot markets (unnegotiated sales) were at ca. 40%, while contract durations with < 1 year, 1-5 years, or >5 years were at 50%, 10% or 20%, respectively (excluding holding companies).

The concept of the present study emerged from a discussion between MSTSZ and AKI. As a stakeholder organisation, MSTSZ tasked AKI to identify shortcomings in the existing price setting methods on the pork market in Hungary, which would gather the different market players under a common flag in order to better understand the rationale of pork price volatility. To grasp the drivers of fluctuation in commodity price returns has been at the forefront of scientific curiosity for a long time. The pork cycle was among the first described economic supply models in history (Szűcs and Vida, 2017), and its price variability has a well-known seasonal component (Utnik-Banaś, 2022).

Over time it became clear that pricing based on benchmark markets is no longer satisfactory for market agents, so we resorted to dynamic comparisons in our research.

We estimate here the spillover effect that helps to differentiate the forecast error variance in one market from the shocks in other markets (Szenderák *et al.,* 2018; Szenderák, 2018; Szenderák *et al.,* 2019; Abdallah *et al.,* 2020; Just and Echaust, 2022). The algorithm developed by Diebold and Yilmaz (2009, 2012) emerged after the global financial crisis and became an established methodology in financial interconnectedness analyses. Its popularity can be ascribed to melding of econometric modelling and Big Data approaches (Diebold and Yilmaz, 2023). It measures association between variables based on generalised vector autoregressions generated forecast error variance decompositions (Pesaran and Shin, 1998), in which forecast error variance decompositions is invariant to variable ordering. This method evaluates what percentage of the error variance of a variable's prediction is influenced by the effect of another variable. It captures both total and directional components, which ultimately answers the question of what the origin of the price fluctuation and its spillover effect is.

Using the Diebold and Yilmaz approach, meat was found to be one of the most significant net pairwise receivers of connectedness at all time periods among the investigated agricultural commodities (Kang *et al.,* 2019). In addition, tails price risk spillover analyses of the U.S. pork and beef sectors revealed that pork industry had a lower price risk connectedness between 1980 and 2020 (Fousekis and Tzaferi, 2021). The Diebold and Yilmaz method was used to reveal that geopolitical events can result in a closer connection of the agricultural markets (Just and Echaust, 2022; Gong and Xu, 2022), during which oil can play a net receiving role against food and agricultural raw materials (Dahl *et al.,* 2020).

A complementary method to uncover time-dependent coupling between time series is entirely model-free (Torrence and Compo, 1998). Unlike other econometric techniques, wavelet does not estimate volatility. Instead, wavelet extracts volatility information using frequency-dependent windowing without having any assumption on the statistical properties of the underlying data. Wavelets are particularly effective at detecting signals that last for only a limited time and show nonlinear dependence in different time periods. It has proved to be a valuable tool in helping to decipher hidden dynamics in raw data in a wide range of disciplines e.g., climatology, psychology, neuroscience, and finance (e.g. Grinsted *et al.,* 2004; Hu *et al.,* 2017; Ng and Chan, 2018). To date, only a limited number of papers applied wavelet methods in the study of volatility transmission between markets (e.g. Albulescu *et al.,* 2017). To our knowledge, this is the first report that complements volatility spillover results with the recently revised partial wavelet coherence method (Hu and Shi, 2021).

A systematic description of the agricultural market interdependence in European settings is still far from complete in the literature. Accession to the European Union increased the speed of price transmission between the old MSs and the newly joined countries, and pork price is an exemplary model among the major agricultural commodities that has experienced a great deal of turmoil since then. The aim of this paper is thus twofold. We identify and retrospectively analyse the dominant factors shaping pig producer prices in Hungary. Along those lines, we also uncover how transmission of market information can be deduced from the volatility of pig prices, thereby identifying the direction of interlinkage between each actor.

Our results indicate that one of Europe's largest pig producer country, Germany – which has long played a key role in global pig output – has had a tangible effect on pig producer prices in Hungary since at least 2015. Germany's mounting influence can not only be tracked down at individual MS prices but on the average European price as well. This however does not imply that Germany has a unilateral influence on the composite European price, as our approach unveils different periods when German and European prices differed. In a Central and Eastern European context, the influence of national markets bordering Hungary is also evident, but their impact is more subdued.

Methodology

The time series used in our study spans over 14 years of weekly updated entry price to the slaughterhouse (pig producer price; without VAT and transport costs) from the beginning of 2007 until the end of 2021. Missing data were filled in by linear interpolation. Prices were recalculated for Hungarian currency (HUF) at daily exchange rate. Chicago Mercantile Exchange (CME) Lean Hog front month futures contract quotes were used as the US pig price. The time series were transformed to log returns due to the possible multimodal/non-normal distribution, which can be interpreted as percentage changes for small values (transformation into a record of percentiles as per Grinsted et al. (2004) did not change results; data not shown). The absolute values of the logarithmic returns were used as a proxy for volatility.

The Diebold –Yilmaz (DY) spillover index

The Diebold and Yilmaz (2009, 2012, 2023) spillover index is based on a variance decomposition from an *n*-variable *p* order covariance stationary difference vector autoregression model (DVAR) model:

$$x_t = \sum_{i=1}^{p} \Phi_i x_{t-i} + \varepsilon_t \quad (1)$$

The variable x_t denotes the analysed price series in time *t*, Φ_i is the parameter matrix, while ε_t is the error vector term, which is assumed to be independently and identically distributed with zero mean, thus $\varepsilon_t \sim IN(0, \Sigma)$. During the calculations, the forecast error variance can be decomposed to own and cross variance shares. The spillover index simply measures the ratio of the own and the cross variance share to the total forecast error variance, expressed in percentages. The variance decomposition is dependent on the ordering of variables, which is introduced by the Cholesky decomposition, which is a precondition to achieve orthogonal innovations. As a significant improvement, Diebold and Yilmaz (2012) modified the index based on Pesaran and Shin (1998) and Koop (1996) generalised variance decomposition. Using this method, variance decompositions are invariant to the ordering. Furthermore, not only the total connectedness, but also directional connectedness is considered. Let us denote

the forecast error variance decomposition (VD) of the *H*-period forecast by $\theta_{ij}^{g}(H)$ in case of *H=1, 2…*:

$$\theta_{ij}^{g}(H) = \frac{\sigma_{jj}^{-1}\sum_{h=0}^{H-1}(e_i' A_h \Sigma e_j)^2}{\sum_{h=0}^{H-1}(e_i' A_h \Sigma A_h' e_i)} \quad (2)$$

Here, σ_{jj} denotes the standard deviation of the j^{th} equation's error, Σ is the variance-covariance matrix of the error vector ε_i, while e_i is a simple selection vector with 1 in the i^{th} position and 0 otherwise. The matrix A_h follows from the moving average representation of the VAR model. Each entry of the variance decomposition matrix is normalised by the row sum as:

$$\tilde{\theta}_{ij}^{g}(H) = \frac{\theta_{ij}^{g}(H)}{\sum_{j=1}^{N}\theta_{ij}^{g}(H)} * 100 \quad (3)$$

Here, $\sum_{j=1}^{N}\tilde{\theta}_{ij}^{g}(H) = 1$ and $\sum_{i,j=1}^{N}\tilde{\theta}_{ij}^{g}(H) = N$ by construction. The rest of the indices can be calculated as the following. The *total spillover index* shows the share of the forecast error variance resulting from the cross-volatility effects. Therefore, it is an indicator of the average connectedness among the variables:

$$S^{g}(H) = \frac{\sum_{\substack{i,j=1 \\ i\neq j}}^{N}\tilde{\theta}_{ij}^{g}(H)}{N} * 100 \quad (4)$$

The *directional spillover* measures the spillovers received by market *i* from all other markets *j*, and the spillovers transmitted by market *i* to all other markets *j* as:

$$S_{i*}^{g}(H) = \frac{\sum_{\substack{j=1 \\ j\neq i}}^{N}\tilde{\theta}_{ij}^{g}(H)}{\sum_{j=1}^{N}\tilde{\theta}_{ij}^{g}(H)} * 100 \quad (5)$$

$$S_{*i}^{g}(H) = \frac{\sum_{\substack{j=1 \\ j\neq i}}^{N}\tilde{\theta}_{ji}^{g}(H)}{\sum_{j=1}^{N}\tilde{\theta}_{ji}^{g}(H)} * 100 \quad (6)$$

The *net spillover index* implies whether a variable is a net transmitter or a net receiver of volatility spillovers (it is simply the difference between the transmitted and received gross volatility spillovers). If the net figure is positive, the variable *i* influences all the other markets more than being influenced by them:

$$S_{i}^{g}(H) = S_{*i}^{g}(H) - S_{i*}^{g}(H) \quad (7)$$

The *pairwise spillover index* measures the spillover effect among two market, *i* and *j*, as the difference between the gross spillovers transmitted from market *i* to market *j* and those transmitted from *j* to *i*:

$$S_{ij}^{g}(H) = \left(\frac{\tilde{\theta}_{ij}^{g}(H)}{\sum_{k=1}^{N}\tilde{\theta}_{ik}^{g}(H)} - \frac{\tilde{\theta}_{ji}^{g}(H)}{\sum_{k=1}^{N}\tilde{\theta}_{jk}^{g}(H)}\right) * 100 \quad (8)$$

The spillover measurement becomes dynamic by using a rolling window method with an arbitrarily chosen time-window and forecast period.

In this study, the AIC and BIC information criteria indicated that the Vector Autoregression model gave a good approximation with a 1-week delay (not shown). Calculation of the DY spillover index on volatility values (absolute log returns) was done with a time window of 100-week and a 4-week forecast period. The model itself consists of the Hungarian pig producer price as the dependent variable and the respective MS data as the independent variable (Denmark, Germany, Spain, France, the Netherlands, Austria, Poland, Romania and the Hungarian imported pig price (IM)). Sensitivity test for the forecast and model lags indicated that the model was not sensitive to the changes of these parameters (not shown). *FrequencyConnectedness* and *testcorr* packages were used to calculate spillover indices and robust correlation in R (Baruník and Křehlík, 2018).

Continuous wavelet power spectrum (wt)

Wavelet theory and its mathematical treatise is described elsewhere (e.g. Torrence and Compo, 1998; Grinsted *et al.,* 2004). The *wt* measures the power of the spectrum of a single time series variable and enables examining local features of a signal, even in the presence of large amounts of noise. As the continuous wavelet transform does not completely deals with boundary conditions on a finite length dataset, a cone of influence (COI) was drawn to demarcate area where the algorithm encountered edge effects and correct data interpretation was impossible (highlighted as semi-transparent area on the graphs). We used Morlet wavelet, as it is widely used for financial applications and it provides both real and imaginary parts, construed as intensity and phase information. The sampling interval was one week.

Bivariate wavelet coherence (wtc)

For studying nonlinear relationships between a data set and a potentially influencing factor, *wtc* was calculated (for the equations of wavelet coefficients see e.g. Grinsted *et al.,* 2004; Hu and Si, 2021). It approximates how coherent two signals are in time–frequency space by examining the intermittent correlation of two oscillatory phenomena based on wavelet amplitudes. The *wtc* can find correlation even in the absence of high common power, and it allows to test for significance of the relationship between the two processes. It is to note, however, that correlation results do not necessarily imply causality. Having no *a priori* knowledge of distribution for the wavelet coherence, statistical significance was tested using the Monte Carlo methods included in the package.

Relative phase differences are shown by arrows on the wavelet coherence plots, which provide details about the delays in the oscillation (cycles) between the two time series under study. The arrows point to the right (left) when the time series are in-phase (anti-phase) or are positively (negatively) correlated. Arrows pointing up (down) means that the first time series leads (lags) the second one by π/2 radians of the local period read off the ordinate scale. Accordingly, directions deviating from perpendicular are considered to show mixed type of behaviour of the two processes.

Partial Wavelet Coherence (pwc)

Any correlation (coherence) between response and predictor variable may be misleading if a third, excluding data set shows significant correlation with the response variable. Partial correlation measures the association between two variables, while it adjusts for the presence of one or more confounding (excluding) variable. Its wavelet application was first proposed by Mihanović *et al.* (2009), generalised by Ng and Chan (2012), and extended to more than one excluding data set by Hu and Si (2021). Previous code implementation based on the real part of the complex bivariate coherence was corrected by Hu and Si (2021).

In analogy to the partial coherency of multivariate spectra (Koopmans, 1974), the modified *PWC* method is defined as the localised correlation in the time-frequency domain. According to Hu and Si (2021), for an arbitrary number of excluding variable the complex *pwc* is defined at scale *s* and location τ as

$$\rho^2_{y,x\cdot z} = \frac{|1-R^2_{y,x,Z}(s,\tau)|^2\, R^2_{y,x}(s,\tau)}{(1-R^2_{y,Z}(s,\tau))(1-R^2_{x,Z}(s,\tau))} \quad (9)$$

where *y* is the response, *x* is the predictor and Z is the excluding variable ($Z = Z_1, Z_2,...,Z_q$), while $R^2_{y,Z}(s,\tau)$ and $R^2_{x,Z}(s,\tau)$ are the squared bivariate wavelet coherences between *y* and *Z* and *x* and *Z*, respectively (Hu and Si, 2021).

During the analysis, *wtc* was regularly checked on each variable pairs of a *pwc*, because *pwc* is prone to produce false positive correlation close to the COI (Hu and Si, 2021). The correlation was ignored, if high local correlation appeared after excluding one or more data sets by partial correlation relative to the bivariate correlation.

Results

Even though the European Union acts as a single market, noticeable differences exist between the different MSs. The time series of weekly pig prices show significant interannual variability from 2007 to present (not shown). A closer look at the sampled markets showed intermittent variability on top of interdecadal dynamics. As a preliminary step, we divided the logarithmic return time series of each MS's price quotation (H-Hungarian, E-average European, A-Austria, D-Danish, G-German, F-French, N-Dutch, P-Polish, R-Romanian, S-Spanish pig prices) into equidistant periods in time (2007-2009, 2010-2012, 2013-2015, 2016-2018, 2019-2021). Robust correlation values (Dalla *et al.,* 2020) were calculated for the entire period between 2007-2021 and for each of the triennials to examine the significance of cross-correlation in bivariate time series. These measures are robust against random variables characterised by different types of finite time-varying variances (heteroscedasticity), and against dependencies in the time series or in relation to each other.

Pig producer prices are defined as the slaughterhouse entry price of pigs. The Hungarian pig producer price (denoted here as H) was used as a proxy for the Hungarian pig industry and was used as the central dependent variable in subsequent analyses. For the entire 2007-2021 period, the correlation value (r) of the pig producer price in the major European Union producer countries with the Hungarian price ranged between 0.34 and 0.63 (correlation data are not shown). The value of the correlation with the pig producer price in Germany (G) was medium (r = 0.55), and between 0.54 and 0.63 for the pig producer price in Austria (A) and the Netherlands (N). For prices in Romania (R), France (F), Denmark (D) and Spain (S), the same value varied between 0.34 and 0.39. During the entire 2007-2021 period, the influence of individual MSs on prices in Hungary (H) changed continuously, while the evolution of the EU average price (E) was less sensitive to these changes, so the correlation with the EU27 average (E) became decisive over the entire length of time (r = 0.66).

Looking at the development of the producer price of Hungarian pig producer price (H) for the shorter period of 2007-2009, its correlation with the EU market (E) was generally weak (0.3), but with the pig producer price in Poland (P) was the highest (r = 0.34). The producer price in Germany (G) did not correlate with the Hungarian price (r = 0.13), unlike the German piglet price (Gpig) that reached 0.33.

From the start of the decade (2010-2012) the most important pig producing MSs began to play an increasing role in setting the Hungarian pig producer price (H). Supply chain integration improved in Hungary and leading Hungarian slaughterhouses started to base their pricing on the German ZMP base price (Marczin *et al.,* 2020). Despite these events, German base price (G) did not yet have an impact on the correlation data at this time (r = 0.44). However, the correlation value of the pig producer price in Poland (P) rose from 0.34 measured in the previous three years to 0.69, implying its co-movement with H.

The 2013-2015 period brought about the full market integration of the Hungarian pig producer price (H) with the EU market. The correlation coefficients were typically already above 0.8, at which point the pig producer price in Austria and the Netherlands showed the closest correlation with the price in Hungary, while the average price in Poland and the EU did not lag far behind this value either.

The period starting in 2019 was strongly influenced by the hectic market conditions. The German pig producer price (G) reached a high of 0.66 among the correlation coefficients for the producer price of Hungarian pigs, followed by the German piglet price (Gpig; r = 0.63). Both were, however, surpassed by the EU average pig price (E; r = 0.70). The corresponding values of pig producer price in Poland (P) and Austria (A) were slightly less (r = 0.59 and 0.61, respectively) than the price in Germany (G) in this recent period.

To summarise, the overall connectedness of the pig markets in our analysis increased considerably over the last two decades. Taking into account the correlation results, we can tentatively distinguish at this point two main periods of market drivers affecting the Hungarian pig supply (H): an early period characterised by more balanced bilateral ties until around 2014 and a later one with a dominant pan-European (mainly German) impact.

The correlation results provided evidence of strong dependence in the different commodities but were unable to capture the time-varying pattern of price changes over

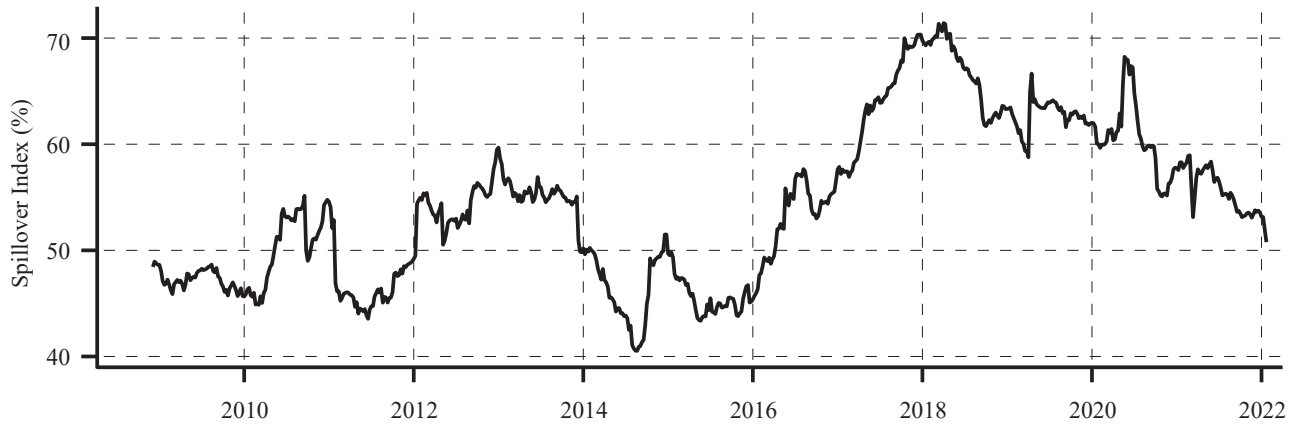

Figure 1: Total volatility spillover index of the Hungarian pig producer price (in percent).
Source: Own composition

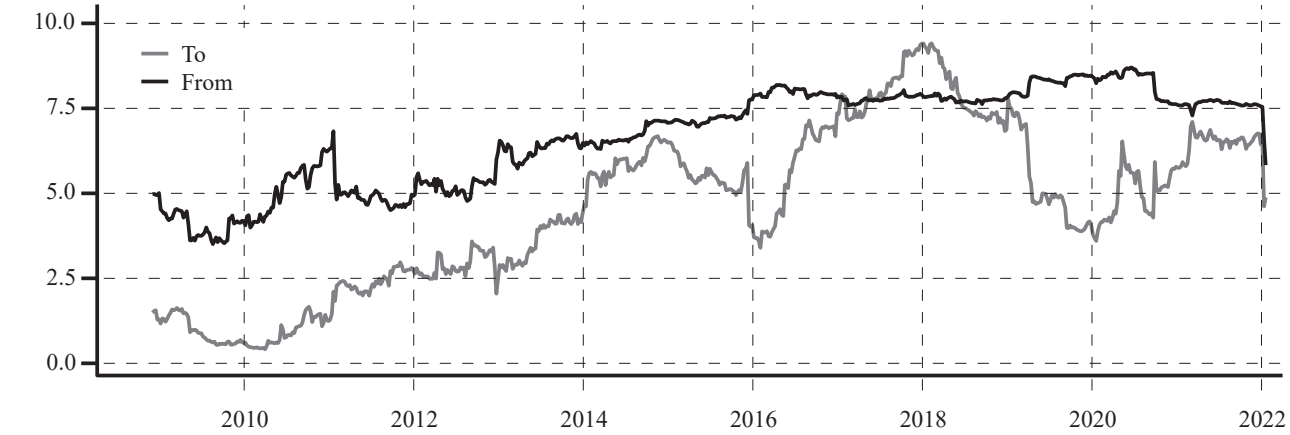

Figure 2: Directional volatility spillover index of Hungarian pig producer price (transmitted and received).
Note: 'To' shows how much spillover effect is directed by the Hungarian market to all the other MS markets, whereas 'From' can be interpreted as how much it received from the others.
Source: Own composition

time, so we turned to a more dynamic approach to detect country-wise connectedness. The concept of spillover effects stems from the recognition of econometrics that the volatility of financial markets increases during crises and spreads onto other markets. In our analysis, we used the modified volatility spillover method from Diebold and Yilmaz (2012) to measure the extent to which price fluctuations of a given market affect the volatility perceived in other markets.

A full-sample dynamic analysis of volatility spillovers was performed between the Hungarian (H) and the different MS markets. Analysing volatility spillovers over time helped us to identify connectivity patterns with high confidence in the constantly evolving European pig market landscape. Because of the applied 100 week-long rolling window sampling, data are plotted only from 2008.

First, we calculated the total, and directional volatility spillovers for the Hungarian pig producer price (H) using the standard VAR estimate (Figure 1). The level of volatility spillover was relatively low at the onset of the observed period and fluctuated between 45% to 50% for the first two years. After 2010, the evolution of the Diebold-Yilmaz total spillover index remained unsettled (Figure 1), followed by a minimum after 2014.

ASF virus entered the territory of the European Union in 2014, which caused great economic damage and had a lasting negative impact on the pork trade due to restrictions imposed on the import of pork from infected areas. It first appeared in Poland in February 2014, and for this reason Russia, which was one of the major export markets at that time introduced an import ban on live pigs and pork from the entire territory of the European Union. Due to strict environmental protection rules affecting animal farmers, pork production in China decreased by 4 percent in 2016 compared to the previous year, which generated huge demand for imports from mid-2016 and caused a price increase on the EU market for slaughter pigs. Given this international exposure, the Hungarian pig producer price (H) surged to a record high by 2018. The ASF virus was first detected in wild boar in Hungary in April 2018, and since then, around 33 countries have restricted the import of pork and meat products from Hungary, most of them – including China, Japan, South Korea and Taiwan – for the entire territory of the country. Since then, only a slow regression of the volatility spillover index has been noted, thus the index continues to be higher compared to the first half of the decade.

By plotting the value of spillovers received (*from*) and transmitted (*to*) by the dependent variable (Figure 2), we obtained the directional components of the volatility spillovers for the Hungarian pig producer price (H). Except for a short interruption in 2017, the Hungarian price (H) was always a net receiver in terms of inter-MS spillovers.

So far, we focused on the gross directional spillover effects. Below, we calculate net spillovers for the Hungarian pig producer price (H) to show how much spillover it transmitted and received from all the MS included in this study. When the value of a particular asset lies above the baseline, the commodity transmits more volatility to the others than it receives from them in that particular year. In such a case, that commodity is called a net spillover transmitter. Negative values correspond to net spillover that a commodity receives from the others and thus the asset acts as a net spillover receiver.

Figure 3 shows net spillover results of the different MSs and demonstrates that all of them can take both positive and negative values at some point. The index of the Hungarian pig producer price (H) remained mostly in the negative range, which implies that this variable mainly played a net volatility spillover receiver role under the market conditions prevailing throughout the entire period. Qualitatively the same result applies to imported slaughter pigs in Hungary, albeit at a reduced level.

Breaking down the net (transmitted-received) spillovers by country, the pig producer price in Germany (G) has been a net volatility transmitter since 2013. Increasingly, the same price in Poland (P) and Austria (A) have also started to play a transmitter role in the European pig market since 2017. However, net spillover has weakened in all three cases due to the pandemic and the outbreak of African swine fever disease. In contrast, the cross-border spillover effects of Dutch (N) and – to a lesser extent – the Romanian prices (R) dominated the first half of the analysed period, indicating that a large-scale reshuffle has taken place in the intra-EU market around 2015.

In volatility spillover plots, timescales are aggregated, so the exact conditions under which a net receiver position turns into a net transmitter position (or vice versa) remains elusive. For an accurate picture of interdependence between national pig prices, we mapped the dependence structure, structural break points and the lead–lag relationships between the individual variables. To unmask these relationships, a wavelet-based approach was chosen because

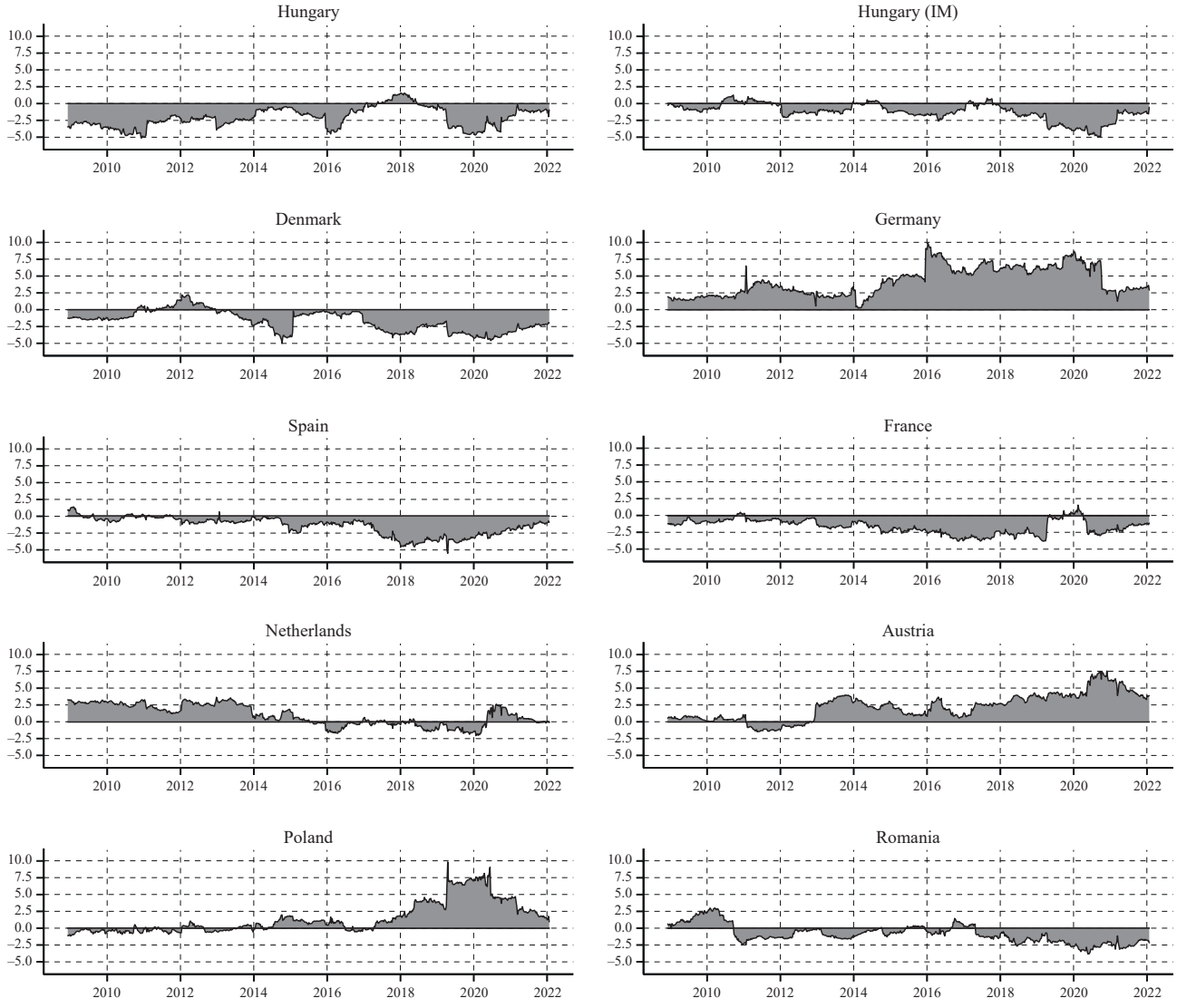

Figure 3: Net pairwise volatility spillovers of the indicated country's pork price with Hungarian pig producer price.
Source: Own composition

this mathematical tool is ideal to expand the data content from the time domain into different layers of frequency representation. Splitting non-stationary and complex time-series up into different frequency components allows us to look at long-term movements and high-frequency details at the same time, as economic decisions and actions are often realised at overlapping timescales. As a reference for subsequent discussions, we consider investors on pig market to be heterogenous with respect to the time horizon they trade (or conclude their purchase agreements). Accordingly, we make a distinction between short-term relationship up to 16 wk, medium-term between 16-64 wk, and long-term above 64 wk period bands on the scalograms.

First, we evaluated for each of the time series to define the dominant modes of local variance (Appendix 1., first column). The continuous wavelet power spectrum of each standardised weekly price series showed that the dominant scale of price fluctuation was very similar (shown for A, G, P, R, E and CME; from wt::A to wt::CME). Local variance of the signal was high in the medium-term range (32-64 wk) between 2013–2018, but other high variability, non-significant regions were also present over the entire timeframe (in the 8-64 wk band).

Wavelet coherence is helpful for elucidating which of the multiple input variables (predictor or independent variable) contributes the most to the response variable (Appendix 1, second column). Pairwise comparison from bivariate wavelet coherence (wtc::H~G) detected a very high degree of coherence between the Hungarian pig producer price (H) and the German price (G). Strong coherence was present between the two variables, particularly over an investor's time horizon of more than one year, which agrees well with the net spillover results discussed previously. Only on the spot market was the relationship erratic (short-term, < 4 wk period band). We found qualitatively the same result, when the Hungarian pig producer price (H) was compared to EU average (E) price (wtc::H~E).

On the graph, the in-phase relationship of Hungarian (H) and German (G) (or European: E) prices is demonstrated by the large number of phase arrows pointing right (wtc::H~G and wtc::H~E). However, as the period decreases on top of the scalogram arrows start increasingly to point upwards, indicating that German (G) (or European: E) price not only co-moved but led the Hungarian price (H) on spot markets by ca. half cycle (1 wk). A similar 1 wk lag was indicated by vector autoregressive model (VAR) calculations (not shown; Szenderák et al., 2019). Albeit at a slightly reduced level than previously shown, the Hungarian price (H) also showed an extensive correlation with the Austrian (A) and Polish prices (P) (wtc::H~A and wtc::H~P). A gap appeared in 2014 on both graphs in the 16 wk band that resolved after 2015, which is probably related to the market turmoil caused by the first report on ASFV incidents in the EU.

The bivariate coherence results demonstrate that most MSs' pig prices correlate extensively with the Hungarian price (H). This implies that some, so far unknown external factors (excluding variables) might influence both the Hungarian (H) (response variable) as well as the chosen MS's pig price (predictor variable) at the same time. If an excluding variable is indeed present, this could lead to an overestimation of the predictor variable's effect on response variable. Hence, we used an improved partial wavelet coherence method (*pwc*; Hu and Shi, 2021) to overcome congruence after excluding one or more common dependent variables (Appendix 1, third and subsequent column). For example, when an additional time series was removed from the H-G relationship (e.g. Austria; see pwc::H~G-A), the reliability of the test improved, but a large swathe of the previously significant region disappeared. Furthermore, if we excluded the effect of more than one data set (e.g. Austria, Poland and Romania; pwc::H~G-[A+P+R]) the resulting plot explained even less amount of variations. One likely explanation is that these excluded variables already contained a large amount of variance from the German time series and themselves were influenced by the German price. Again, the pattern for the European price was very similar to the German price (pwc::H~E-[A+P+R]), underlying the dominating role of E and G in setting the MS prices.

On all previous graphs, G and E showed very similar pairwise or multivariate coherence patterns (e.g. wtc::H~G and wtc::H~E). This raises the question if the average European price serves just as a proxy of the German price, or it shows some distinguishing features. To answer this we compared their partial wavelet coherence with H by switching the order of the predictor and excluding variables between G and E. Comparing the partial coherence pattern of pwc::H~E-G with the complementary pwc::H~G-E, a large band was present from 2014 onwards. When the E was the predictor variable, significant coherence was limited only within period-scales of about 32-64 wks, whereas G being the predictor variable, the band shifted to 64-128 wks. Obviously, H was affected by G and E at different time scale (or period) when the effect of another variable was excluded. This observation underlies the importance of taking care of the period information and implies that after 2014 European price changes were adapted more quickly in Hungarian pig supply contracts than the German price changes.

Other Central and Eastern European producers have a less obvious impact on the Hungarian price (H), such as from Romania (R) (wtc::H~R). Here, there was a stable positive correlation in the medium-term period (32-64 wk) band over the entire time length. On top of it appeared a transient "bulge" in 2017 in the Hungarian - Romanian time series at around 16 wks. If we removed the confounding effect of the German price (pwc::H~R-G) from the Hungarian-Romanian relationship, we could uncover a transient, in-phase association of Hungarian (H) and Romanian (R) prices around 2017. This is perhaps due to the increased Romanian demand for live pigs and pork from Hungary in 2017, as ASF outbreak on Romanian smallholders' live pig output caused a bottleneck in domestic supply at that time (Popescu, 2020). The wavelet result compares well with DY volatility spillover calculations. As demonstrated in Figure 2, Hungary's 'transmitted' spillover surpassed its 'received' position only during this time period.

The "bulge" disappeared entirely by removing the effect of G (pwc::H~R-G). Qualitatively the same result was obtained if we checked the association of R and G excluding the variable H (pwc::R~G-H). This time, however, phase arrows pointed up and left, indicating an anti-phase relation-

ship where G leads R by approximately half a period (ca. 16 wks). The most likely explanation for these observations is that Hungary played a major role in relieving Romanian live pig shortage by expanding its export to Romania, while increasing imports from Germany, so the "bulge" disappears if either H or G is excluded from partial coherence.

Another conspicuous phenomenon is apparent on the partial coherence plot of H and R, controlling for P (pwc::H~R-P). From 2013, a statistically significant, high coherency band appeared that creeped diagonally on the scalogram, while its characteristic period continuously increased. When we included more than one excluding data set (e.g. pwc::H~E-[A+P+R]), the correlation result got more fragmented. Care must be taken in interpreting these results, as multiple (more than one) confounding variables might be present in our pig price system. Here, the German price (G) is definitely one of the major candidates that might have a marked influence on other MS's pork prices.

Despite the ongoing pig market integration within the EU, the United States – with a global market share of 12% – is also able to influence internal producer prices. The dependence on U.S. prices can best be understood, if we compare the Hungarian price (H) with U.S. hog prices published by the CME Group (wtc::H~CME). The bivariate comparison showed a significant level of correlation after 2014 in the midterm period band, where upward facing arrows indicate a prompt impact of U.S. price on H. This remained stable even if we exclude the effect U.S. dollar exchange rate (pwc::H~CME-USD), but diminished almost completely when the German price was excluded (pwc::H~CME-G). We regard this as an indication that Germany acts as a lever to convey world market impact on other MSs, like Hungary.

Market competitiveness requires streamlining supply chain. For the pork industry this translates – among others – to the need to detach piglet production from the fattening phase, with consequences on market dynamics. Submarket analysis of German piglet price on the Hungarian price (H) revealed a rather extensive coupling between the two. It was nonetheless only significant in the medium-term range (32-64 wk) between 2014-2017 (wtc::H~Gpig), when we compared it to the continuous wavelet transform of German piglet price (wt::Gpig). Omitting the German price (G) from the comparison of H and Gpig (pwc::H~Gpig-G), a strip appeared in the same period band that showed a counter-phase relationship between the two prices. Arguably, piglet price serves as an input in a product chain that influences swine stock size, ultimately affecting pig price as output.

Discussion and Conclusions

In this paper, we studied market connectedness of the Hungarian pig industry between 2007 and 2021. In the first part, we studied the volatility spillover behaviour of a set of national pig price time series (Diebold and Yilmaz, 2012) that represents each of the major European producer's net position. Based on the net volatility spillover results, we noted that the Hungarian price's association was the strongest with the German price. It was stable over the entire analysed period but declined somewhat in 2021 in the aftermath of the Covid-19 pandemics. Austria also transmitted a sizeable amount of spillover to Hungary starting from 2013. Polish market pressure built up only after 2018, reached a height in 2020 and subdued afterwards. Other competitors' (Romania, Denmark, the Netherlands) net spillover receiver or transmitter position remains less conclusive. It is to note that Romania, as a Black Sea basin country, has slightly different market access opportunities than the rest of the studied countries. Granger causality test indicated that there is a bidirectional causality-in-variance information flow between international and local pork prices in this country (Guo and Tanaka, 2022).

In the second part of our study, we extended our spillover study with wavelet analysis in order to study the gradual shift in geographical pattern and to better estimate the hierarchical structure of the drivers of price volatility. Pairwise wavelet coherence (*wtc*) of the various countries with the Hungarian pig price showed an almost homogenous wavelet coherence pattern. But removing the effect of each individual country one-by-one in partial coherence (*pwc*) revealed a different amplitude and phase relationships that was not apparent in the pairwise (*wtc*) results. As Holst and von Cramon-Taubadel (2013) pointed out, price transmission works even in the absence of physical trade. Unexpectedly, the German market's predominant correlation appreciably weakened when more than one excluding variable was used. One explanation could be that traders from Austria, Poland, and Romania, which are also active in Hungary, base their pricing on the German market price and this business practice partly offsets the German component observed in Hungary. The calculated average European pig price was even more predictive for the Hungarian price, than the German price. Our finding supports the view that the Hungarian price is coupled to the European price the most efficiently.

The limitations of this study are manifold. Pork meat is a cost-driven commodity in the international trade (Hoste, 2018) and its price is linked to inflation and business cycles. In a preliminary assessment (not shown), we explored several potential input factors affecting production costs or substitute product prices (e.g. chicken meat), but few of them had a notable effect on the Hungarian pig price. Pork prices also seem to be resilient to feed price variability (e.g. feed maize, oilseed). This may be related to the fact that deepening relationship between grain marketers and grower-integrator is already under way or on the agenda of many pork producers. The spot market of pig is thus expected to shrink in the long run.

Forward-pricing in futures market might be a tool for producers to alleviate risks traditionally associated with agricultural spot markets and to decrease volatility in prices (Wang *et al.,* 2021). A sizeable number of transactions must take place as a requisite, but in terms of capitalisation, the European futures market for live pig is minuscule compared to the U.S. hog market (Ziegelbäck and Kastner, 2013, Adämmer *et al.,* 2016). Instead, price swap was recently proposed as a remedy for pork meat producers that would force buyers to reveal their reservation price (Lievens *et al.,* 2021) and would put producers in a better position.

Another limitation of our study is related to the constraint of the sampling theorem for adequate data frequency. In fact,

the finite number of samples in price time series poses a limit for the maximum attainable time resolution of a wavelet transformation, which – using the Morlet as a mother wavelet function – limited us to a couple of weeks in this study, severely underestimating fast market decisions.

From the many branches of animal husbandry, the European pig industry is remarkably vulnerable to shifting patterns of consumer behaviour, trade disputes, ASF occurrences and tightening regulatory standards. To tackle these challenges, the industry is on the verge of major changes (Faris and Rehder, 2019). Hence, further studies are needed to investigate how connectedness of pork markets across the European Union will change as a result of these measures.

In general, international trade moderates price fluctuations of commodities that experience cyclic production. Despite this, our results indicate that the intra-European pig market price fluctuates heavily, and this influences producers' margin and thereby farm income in Hungary. There does not seem to be an end in sight to the price volatility, as upcoming animal welfare regulations will likely further exacerbate the situation. The information presented here is intended for the actors in the pig industry to set their investment decision and price negotiation tactics accordingly.

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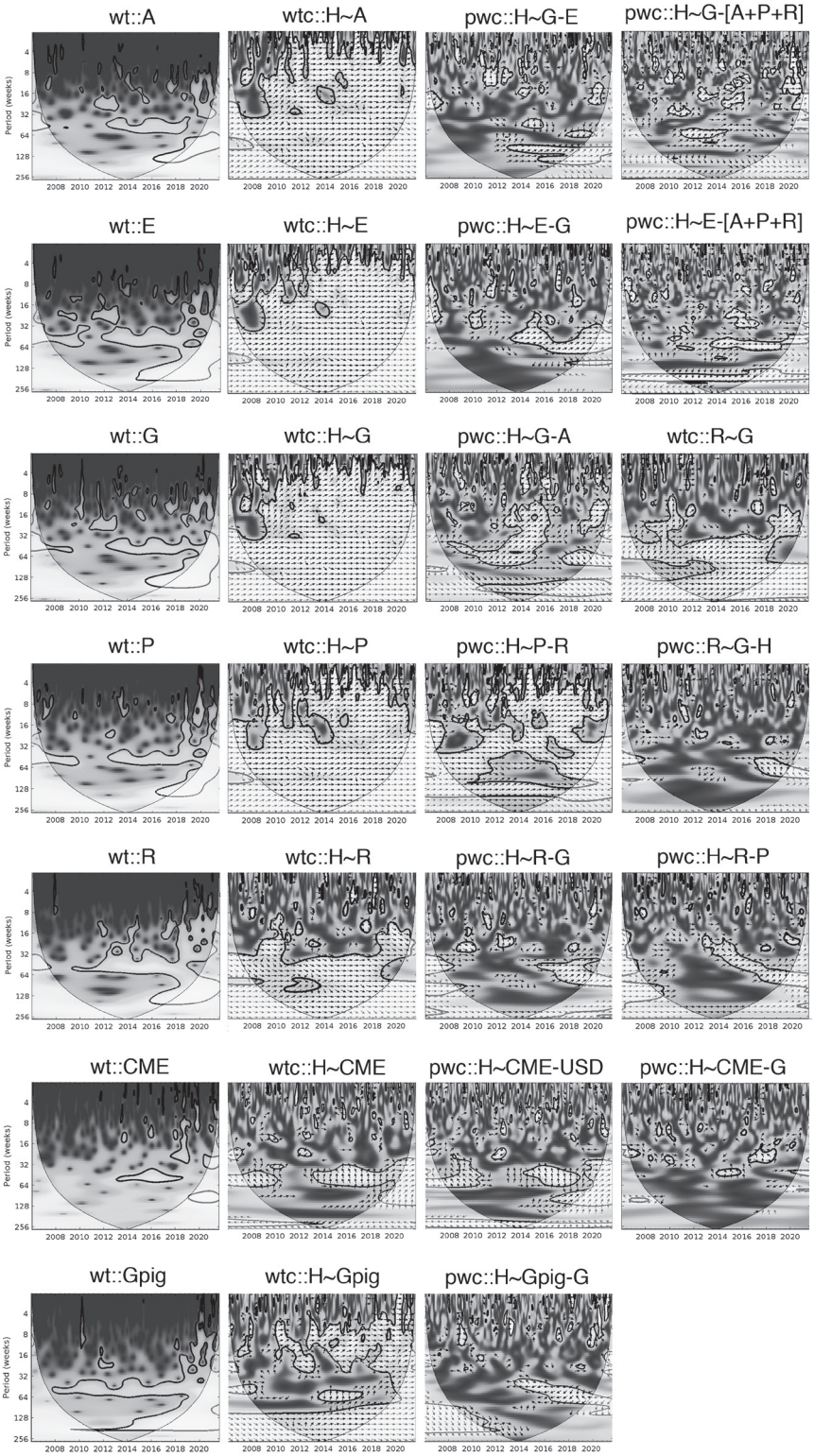
Appendix

Appendix 1: Continuous wavelet power spectra (wt, first column) of the indicated variable. Bivariate wavelet coherences (wtc, second column) between the response (1. position in graph title) and the predictor variable (2. position). Partial wavelet coherency (pwc, third and subsequent columns) of pig prices measured between the response (1. position) and the predictor variable (2. position), while excluding the effect of the confounding variable(s) (3. position).



Abbreviations: A: Austrian pig price (p. p.), CME: U.S. hog price, G: German p. p., Gpig: German piglet price, H: Hungarian p. p., P: Polish p. p., R: Romanian p. p.
The data are sampled weekly. Time (years) is shown on the horizontal axis of the scalogram, the vertical axis refers to the inverse of frequency (period in weeks), while local wavelet power (variance) is intensity-coded. Bivariate wavelet coherence plots highlight those areas in the time-frequency space where the two variables co-vary. The warmer the colour, the higher the coherence is (interpreted as correlation) at that position of the time-frequency plot. A bold line delineates statistically significant areas of coherence. Arrows correspond to the phase angles of the wavelet spectra. Cones of influence are shaded, and thick solid lines show the 95% confidence levels computed by Monte Carlo simulations.
Source: Own composition

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Factors influencing farmers' willingness to participate in Farm to School programmes – The case of Albania

Farm to school (F2S) programmes ensure school pupils receive an appropriate diet, fight malnutrition, and motivate children to attend school. The participation of local smallholders in F2S schemes contributes to these objectives, but also provides a market opportunity for local small farms. This is particularly important in the case of developing or emerging economies that are characterised by malnutrition among children and where smallholdings often struggle with limited market access, as is the case with Albania. The aim of this paper is to explore the main factors affecting farmers' willingness to participate in a F2S scheme using data from a structured farm survey. Regression analysis results show that economically based motivation (farm-related factors such as size and post-harvest losses) intertwined with social capital factors and attitudinal indicators (experience and attitudes towards cooperation, reliance on local governmental support, information, and product safety perception level) affect farmers' willingness to participate in F2S schemes. For farmers to participate viably in such schemes, it is necessary to provide knowledge, awareness, and support for ensuring compliance with food safety and quality standards and for improving cooperation.

Keywords: Farm to school, farmer, willingness to participate, Albania

JEL classification: Q13

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Introduction

School food and nutrition programmes are tools that can help ensure an appropriate diet for school pupils, fight malnutrition, and motivate children to attend school. Such programmes are well established in most advanced economies such as United States, Australia, and many European countries. In developing or emerging economies, such programmes are even more important, given the widespread malnutrition among children and market access challenges faced by many poor smallholders (Sumberg and Sabates-Wheeler, 2011). Unfortunately, a combination of a lack of government policies, limited financial resources and a lack of institutional capacity to operate school food programmes often prevents the establishment of food nutrition programmes (FAO, 2019).

Food nutrition programmes are the basis for establishing farm-to-school (F2S) schemes. These schemes are becoming a viable avenue for positively impacting children's dietary habits as well as the sustainability of the entire food system (Feenstra and Ohmart, 2012). F2S schemes also contribute to reducing food waste, educate children about healthy food practices and ensure that pupils follow a balanced and healthy dietary regime (Botkins and Roe, 2018). On the other hand, these initiatives aim at integrating local small farms into school food and nutrition programme schemes, subsequently improving their access to market (Plakias *et al.,* 2020) and improving the local economy (Bauman and McFadden, 2017). While developed countries have evolved into new stages of F2S schemes (such as reducing food waste, improving child education, increasing dietary diversity, educating youth on nutrition, and strengthening cultural identity), in some developing countries there are emerging the early stages of these schemes (Fitzsimmons *et al.,* 2019). In countries where F2S programmes are weakly developed, it is crucial to analyse farmers' capacity and willingness to participate in F2S programmes. This is also the case with Albania, a post-socialist country where there are no F2S programmes, despite the potential and the need for such programmes.

The integration of smallholder farmers into formal markets depends on a wide range of factors and it can be explored through different perspectives. Joshi *et al.* (2008) argue that framing all supply dimensions – especially those of farmers – as accurately as possible provides the conditions under which programmes can function effectively. While many studies focus on the demand side, including the impact on pupils' nutrition, school involvement and local governance (Bonanno and Mendis, 2021; Wen and Connolly, 2022), only a few scholars have explored the supply issues (Conner *et al.,* 2012, Joshi *et al.,* 2008; Izumi *et al.,* 2010). Botkins and Roe (2018) found that both school characteristics and local farm production factors were associated with participation in F2S, yielding positive effects on both sides. However, according to Conner *et al.* (2012), farms are a key component of F2S programmes and determine the successful adoption of such schemes. The farmers' capacity and willingness to participate in F2S schemes is crucial not only for the F2S programmes but also in the framework of the consolidation of local markets. However, in transition economies, poor organisation of the value chain (weak vertical and horizontal cooperation) is a major challenge (Imami *et al.,* 2013; Gërdoçi *et al.,* 2017), making it more challenging to establish F2S. Despite the

importance of local short food supply chains (i.e. F2S) for rural communities, food quality, children's health and the overall local economy, research on this topic in post-socialist transition economies remains scarce.

According to most surveys carried out in Albania, food insecurity is moderate overall. Rural food security is moderate due to flexible food systems, low population density, high equality of agricultural land ownership/use and abundant, extensively used common land (pastures and meadows), which together represent good conditions for rural communities to access a diversified but highly seasonal food intake. Poor peri-urban and urban families are more exposed to food insecurity. In Albania, many children exhibit poor nutritional status, have unhealthy diets and inadequate physical activity. Underweight and undernutrition remain a concern in some areas (although to a lesser extent when compared to the past) (FAO, 2022). Weak consumption habits are one of the factors. For instance, Hyska *et al.* (2020) found that approximately 63% reported having eaten breakfast regularly. Being overweight among Albanian children – linked to unhealthy or excessive eating and overall inadequate lifestyle – represents a growing problem. The prevalence of both overweightness and obesity was found to be much higher among urban children compared with their rural counterparts (Hyska *et al.,* 2014). Child and adolescent obesity were not common prior to 2000 in Albania but have been increasing over the past decades and according to the latest estimates, account for almost 8% of the child and adolescent population in the country (FAO, 2022).

There are two main challenges regarding food supply chain organisation and farmers' integration in potential F2S schemes. The first challenge relates to the institutional framework guaranteeing food safety and quality. There are gaps in food safety standards throughout the downstream food value chain in Albania. The national food safety control system faces serious problems in terms of legislation, infrastructure, institutional capacity, control, and enforcement (Zhllima *et al.,* 2015). In addition to weak law enforcement, another factor resulting in low food quality and safety is limited knowledge/awareness among farmers about animal diseases, inputs, food safety standards, and their consequences for the health of family farms and end consumers. These issues are exacerbated in the case of livestock, and consequently, meat and dairy products (Zhllima *et al.,* 2015; Gjeci *et al.,* 2016). These constraints make direct procurement to farms without intermediaries difficult to enact. A recent study highlights that pupils, parents and teachers consider food safety to be one of the main concerns/constraints affecting their intention to support or participate in F2S schemes (Hyska *et al.,* 2020).

The second challenge relates to the small size of farms (approx. 1.2 hectares on average) combined with fragmentation (3 or more parcels per farm), which together affect the capacity to comply with (food safety and quality) standards and to achieve efficiency. Access to the market is becoming more difficult for local producers, especially for smaller (and fragmented) farms due to the expansion of supermarket chains, which are more demanding in terms of volumes and standards (FAO, 2022). In the context of the slow pace of the farm consolidation process, given that the small farm size hampers economies of scale (necessary to compete in terms of efficiency), it is necessary to look for alternatives. Since Albanian agriculture (small farms) can hardly compete with large volumes in the local and especially export markets, participation in short (local) value chains is important; this can be linked to F2S.

Despite the importance and potential that F2S schemes represent for children's nutrition (considering both need to improve access to healthy food and preference for local origin) and for local farmers' access in the market, such schemes have not been developed in Albania. After 2013, reforms on Albania's social care and protection systems, aimed to divert a part of economic aid (frequently cited as the only instrument of social protection in the country) to households in conjunction with other instruments such as food for children and other types of assistance were expected to function. However, no major change was experienced, despite the willingness to adopt them. Indeed, since 2012, only one primary school was subject to food nutrition (due to exclusive presence of minorities, namely Roma and Balkan Egyptian children), through the direct provision of basic school meals (FAO, 2019).

In recent years, school feeding programmes have been gaining in importance and have been the focus of policy discussions on how to enable a healthy diet and better education for children. A concrete initiative took place in 2018, aimed at testing/piloting the introduction of a large-scale school feeding programme in Albania. Yet, despite the efforts of a few local governments, the implementation of F2S programmes has not taken place.

Economic and social capital factors as well as experiences and perceptions affect farmers' willingness to participate in coordinated food supply chains, as in the case of F2S schemes. Our objective is to assess the factors that influence farmers' willingness to participate in F2S programmes, in the context of institutional weaknesses in terms of safety and quality infrastructure. The analysis of the Albanian farmers is an illustrative case that can help fill the gap in the literature of post socialist countries.

The rest of the paper is structured as follows: Section 2 presents the literature review which serves as a basis for the hypotheses. Section 3 consists of methods, Section 4 demonstrates the results, while Section 5 concludes.

Literature and Hypotheses

There is a rich literature analysing the system of supply of local food for school feeding programmes (Christensen *et al.,* 2019a; Boys and Fraser, 2019). However, few studies explain the factors determining F2S programmes' feasibility. One of the crucial factors determining the successful implementation of F2S is farmers' capacities and willingness to participate in such programmes (Feenstra and Ohmart, 2012; Botkins and Roe, 2018; Fitzsimmons and O'Hara, 2019). Over the last few decades, especially in developing world, there has been growing research interest concerning farmers' behavioural intentions (beliefs, attitudes, perceptions about a particular decision or outcomes of a decision) and how they affect their farming decisions (Conner *et al.,* 2012, Joshi *et al.,* 2008; Izumi *et al.,* 2010). Following the theoretical arguments of Fishbein and Ajzen (2011), we can expect that attitudes towards a particular behaviour may affect behavioural beliefs and consequently the

intention of carrying it out. Therefore, we study willingness as a prerequisite of a farmer's potential engagement at the point in time when F2S are established.

As was highlighted earlier, food safety is a major concern. According to Janssen (2014), local farmers and school food service buyers have vastly different approaches to food production and handling. Local farmers have developed individually based marketing and handling processes, while school food service personnel focus on regularity and precise record-keeping – thus standards compliance is considered more important than (local) origin. For instance, O'Hara and Benson (2019), who focus on milk procurement in the framework of a F2S scheme, show that the local agricultural conditions (existence of local dairy production) do not strongly influence the probability that a school district sources local foods. This instead depends primarily on the standards of safety and quality to be achieved by the suppliers. Under most procurement rules, including here in Albania, it is not easy to discriminate between producers according to their location, hence quality and safety are the most important standards to be achieved. Even the farmers themselves perceive that product quality and safety chiefly determine how ready for F2S and how F2S-oriented they feel. Thus, we formulate the following hypothesis:

H1: Farmers' perceptions of the safety standards of their production are positively associated with their willingness to engage in F2S programmes.

The structure of the value chain is also an important factor. Higher fragmentation makes cooperation and the role of intermediaries more important. Christensen *et al.* (2019b) found the role of intermediaries in local procurement is key. Although the existence of intermediaries may be important for catalysing sales, on the other hand it may reduce the direct impact and benefits perceived by farmers on being integrated in these schemes of procurement. Thus, another option is collective engagement and cooperation in the value chain. Willingness to participate in cooperatives can enable integration in F2S schemes. Morakile *et al.* (2021) indicate that despite the perceived benefits of belonging to a group in the context of accessing government markets, about half of the smallholder farmers in areas of South Africa would prefer to remain independent from any form of aggregation or farmer group. The majority of the farmers – mainly those who have sufficient individual capacity – would prefer to approach the market individually. If a farmer has had a positive experience of joint activities, their attitude towards cooperation will dispose them favourably towards another type of coordination, such as contract farming. In addition, experience of cooperation practices such as sharing transport among farmers is likely to coincide with an openness to making joint sales through F2S schemes. Hence, our second hypothesis is as follows:

H2: The more favourable the attitudes on cooperation among farmers, the higher the willingness to participate in F2S. Farmers who have previous experience in carrying out joint actions are more willing to participate in F2S.

The existing empirical literature also indicates that there is a twofold picture of indicators, suggesting that farmers' motivations are largely based on social values on the one hand, and economic prospects on the other hand (Hinrichs, 2000; Izumi *et al.,* 2010; Conner *et al.,* 2012; Matts *et al.,* 2016; Nathan Rosenberg *et al.,* 2014). For instance, Izumi *et al.* (2010) found that farmers' motivations for selling their products to schools are market- and socially based: for example, finding new market opportunities for their production, perceived long-term economic benefits and realised social benefits (i.e., introducing children to nutritious foods and local community support). A later study (Conner *et al.,* 2012) builds on these results and empirically groups farmers' motivations so as to differentiate between the market versus social orientation of farmers willing to engage in local F2S programmes; it also explores for other variables. The authors suggest that market-oriented farmers are more willing to invest and incur increased transaction costs to meet F2S programme requirements. Although F2S impacts individual sales only modestly, Joshi *et al.* (2008) find that farmers see F2S as an instrument for additional sales through other venues. One potential added opportunity consists in the view that farmers, beyond profit maximisation, would be able to rely on reducing post-harvest losses. The intention to enter (formal) agreements also aims to address (market) losses. Previous research has shown that farmers who are engaged in contract farming or who have stable relations with buyers have lower losses (Imami *et al.,* 2013). Thus, we expect that:

H3: With an increased level of post-harvest losses, an increased willingness to participate in F2S schemes is to be expected.

Benefits in improved bargaining position through F2S are hampered by farmers' perception that production and/or marketing decisions lack coordination, a lack of (common) storage facilities and limited information. Therefore, there is a fundamental need also to explore the role of information in enticing farmers into F2S schemes. Information is one of the elements that are crucial to increasing trust and reducing uncertainty in market channels. For instance, providing more information on procurement procedures may reduce the perceived difficulties by farmers. The level of perception is also linked to uncertainty. Indeed, research shows that trust, uncertainty and investment in specific assets are key determinants of long-term relationships for Albanian farmers (Gërdoçi *et al.,* 2017). The perceived level of uncertainty is influenced by the level of information that farmers have about challenges (e.g. related to F2S). Thus, the less they are aware about challenges, the lower the perceived uncertainty and the higher the willingness to engage in F2S. This is the basis of our fourth hypothesis:

H4: Absence of information (or awareness concerning challenges relating to food procurement standards) is negatively associated with the willingness to participate in F2S. In addition, a high level of uncertainty is positively associated with the willingness to participate in F2S.

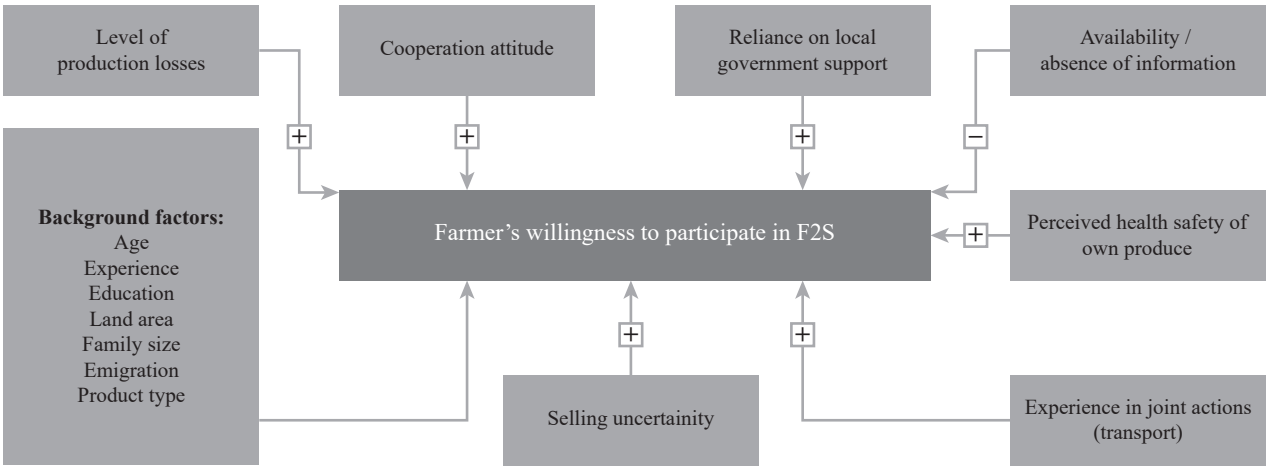

Figure 1: Conceptual framework of the study.
Source: Own composition

Institutional circumstances and the role of local government are also important. Authors such as Bagdonis *et al.* (2009) depict the importance of frame bridging and extension in North America case as strategies for expanding the F2S movement and revitalising the rural community through support of local agriculture. The role of local government is indispensable in enabling two objectives with one action: on one hand, securing stable sales to local farmers, and on the other hand, providing local and safe food to schoolchildren. Farmers are challenged by several barriers, for instance cost of food, labour, equipment, supply quantity, seasonality, distribution, etc. (Izumi *et al.,* 2010; Joshi *et al.,* 2008; Vallianatos *et al.,* 2004; Roche *et al.,* 2015; Feenstra *et al.,* 2011). These barrier factors become highly important issues for countries with weak institutions such as Albania; thus support from (local) government is crucial and farmers perceive local government support to be essential to providing the incentive for their integration into F2S. According to Thompson *et al.* (2014), appropriate state and local level agriculture infrastructure supports (e.g. food safety and good agriculture practice training, market-ready workshops, accessible value-add processing centres, and contract-grow procurement options) should be put in place in order to orient smallholder farmers into F2S programmes. Thus, prior experience with local government support is expected to positively influence farmers' willingness to participate in F2S, which serves as a basis for our fifth hypothesis:

H5: Reliance on local governmental support increases the likelihood of farmers to be willing to participate in F2S.

In our paper, farm and farmers characteristics (e.g. farm size, sociodemographic characteristics of the farmers household, etc.) are also included, which receive attention in behavioural studies but less so in F2S related literature. Matts *et al.* (2016) indicate that small scale farmers are less likely to rate economic factors as motives to participate in such market opportunities and large-scale farmers are less likely to be oriented towards social benefits of participation. Considering the current farm structure in Albania, it is expected that the larger the land area, the higher are the odds that the farmer is willing to participate in F2S, due to produce availability. The household size is a very important labour endowment factor and increases the potential of the farm to be engaged in processes requiring product cleaning, sorting and packaging and other added value activities. Taking into account the high seasonality of production and the need for consistent supply in F2S, farmers engaged in greenhouse production have a higher capability than fruit producers in this regard and may therefore be more willing to participate in F2S programmes.

Additionally, farmers socio-demographic characteristics are important. Age, experience, education may influence farmers' willingness to pursue innovative market channels. While younger and more educated people are expected to be more open to exploring innovative market opportunities, on the other hand, (higher) education can also be negatively associated with farmers willingness to engage, since more educated farmers can be also more reluctant to take the risks that emerge from F2S. Innovation is often endorsed by returning migrants (F2S). Thus, returned migrants may be more able to understand the benefits of F2S.

The conceptual framework of the paper is presented in Figure 1.

Methods and Data

Questionnaire design

In addition to the literature review, focus groups and semi-structured interviews were used to determine the most relevant variables and the type of questions to be used in the structured farm questionnaire. The focus groups (FG) were carried with several stakeholders, namely farmers (FG 1), traders and consolidators (FG 2), municipality and school representatives (FG 3) and catering companies (FG 4). The number of participants to each focus group was from 8 to 12. A guideline was prepared for the focus groups which was divided in subsections according to the topics of the

research, namely the promptness of farmers to supply produce, the sustainability of the schemes, the procurement procedures and the overall system of cooperation and integration. In addition, 35 semi-structured interviews were carried out before and after the structured survey, which were useful both for the structured survey design and for validating or interpreting the findings. A snowball sampling method (Creswell, 2009) was applied to identify the main stakeholders and opinion leaders. The questionnaire was composed of several sections. The first section contains farmers sociodemographic characteristics. The second section contains farm structural attributes, while the third section is composed of questions used to explore farmers attitude and beliefs.

Data collection

The study considers the F2S linkage as a food system and aims to identify its main segments which are crucial to ensure food and nutrition security to schoolchildren during the school day. Structured survey interviews were carried with market-oriented farmers with homogenous product portfolios. Two types of farm profiles were targeted which were characterised by low production seasonality or high storage capacity: i) farms focused on the production of fruits which are more suitable to be stored for longer periods (apples, plums and nuts) and, ii) the greenhouse farms which produce vegetables (e.g. tomatoes, cucumbers, salads) throughout the year. The selection of these two activities is linked with the dietary requirements of pupils, but also with supply provision as being important elements of the products basket to be found in the (Albanian) market, and less risky related to food safety standards (when compared to livestock products), and relatively easy to store, transport and consume. Convenience is important considering that on one hand, there is a lack of premises and logistics at suppliers and schools, while on the other hand, the longer the period of production during the year, the more likely it is for stakeholders to establish stable relations and networks in the value chain and moreover, the greater are the chances to create convenient and enduring menus for children.

After the identification of the main products and regions (Korçë and Fier regions host the largest number of fruit/apple and greenhouse farmers, respectively), farmers were chosen following a two-stage sampling approach. A purposive sample method was applied in two main areas of concentration of these farms: i) the farming communities surrounding the Municipality of Korça with 250 farmers focused on production of apple, plums, and ii) 250 farms[1] of the farm communities surrounding the municipality of Fier (more than 20% of a total population of 1200 greenhouses), which are focused on production of off-seasonal vegetables raised under greenhouse systems such tomatoes, cucumber etc.

After identifying the areas/villages with higher concentration of farms operating in the chosen activity, a random sampling was carried within villages so as to have more variability in terms of structural factors related to the farm producing products of F2S relevance. The sampling frame was limited to market- oriented farms. The selection of the farmers' operators subject of the survey was based on the use of filter questions (farms with less than 0.2 ha of fruits in block and greenhouses with less than 0.1 ha of surface were not selected).

A pilot survey was carried out with 8 percent of the sample using two types of farms, namely greenhouse and fruit farms. The survey was carried by using groups of surveyors (two groups with four members each). The coordination was carried by the authors of this paper (two of the authors were coordinators of the survey), while the implementation was done in cooperation with the agriculture extension services of each region targeted by the survey. Questionnaires were completed using paper-based versions. Following the results of the pilot survey testing, minor changes/editing was introduced to the questionnaire before implementing the full survey.

Sample characteristics

Socio-economic characteristics and other descriptive indicators of the sample are depicted in the Table 1. Only 6% of the sample are women, while 94% are men (this

Table 1: Socio-demographic characteristics of the sample.

Age	No.	Percent	Education level	No.	Percent
<30	96	19.5%	Primary education	258	52.4%
31-40	112	22.8%	Agricultural secondary education	90	18.3%
41-50	111	22.6%	Other secondary education	100	20.3%
51-60	111	22.6%	University	44	8.9%
61<	62	12.6%	Total	492	100.0%
Total	492	100.0%			
Gender	**No.**	**Percent**	**Employment**	**No.**	**Percent**
Male	461	93.7%	Employed in the public sector	13	2.6%
Female	31	6.3%	Employed in the private sector	15	3.0%
Total	492	100%	Self-employed in my company/farm	436	88.6%
			Other (retiree, student, special needs, etc.)	28	5.7%
			Total	492	100.0%

Source: Own composition based on survey results

[1] Of which 30 in Fier (of 68 farms mainly in Strum, Zharrëz, and Frakull), 150 in Lushnje (of 830 farms mainly in Krutje dhe Bubullimë) and 70 between Berat and Fier (of 307 farms mainly Kutalli).

Table 2: Key descriptive statistics for surveyed farms.

	Indicator	Mean	Std. D	Min	Max
Orchard farmers	Age	50	14.1	20	79
	Cultivation experience of the main product (no. of years)	16	7.0	2	30
	Total agriculture land area (dynym[a)])	22.2	15.3	3	82
	Land area under orchards (dynym)	12.8	10.0	2	70
	Unused (fallow) land (dynym)	0.9	2.4	0	14
	Indicator	**Mean**	**Std. D**	**Min**	**Max**
Greenhouse	Age	41	12.2	19	75
	Cultivation experience of the main product (no. of years)	10.6	6.9	1	30
	Total agriculture land area (dynym)	12.0	9.7	2	80
	Land area under greenhouse vegetables (dynym)	3.6	2.9	1	30
	Unused (fallow) land (dynym)	0.6	1.8	0	16

[a)] 1 hectare is equal to 10 dynym.
Source: Own composition based on survey results

indicator corresponds to the share of households' heads in rural communities (FAO, 2020)). Most of surveyed farmers have completed primary education (52%), 89% of them are (self) employed in the agriculture sector (agricultural activities being the main source of household incomes).

The average area cultivated is relatively small, around 1.3 hectares for orchards and 0.36 hectares for greenhouses respectively (Table 2). Consequently, volume production and the income from sales appear to be limited. Farmers involved in the greenhouse sector are relatively younger than the ones included in the orchard sector, and subsequently also their experience in the farming sector is lower than fruit trees farmers.

Data analysis

Data cleaning took place by using descriptive analyses based on calculated averages and addressing outliers. Furthermore, the questionnaire had control questions (interlinked questions) to validate the quality of implementation. After data cleaning, the sample reached 492 valid observations. Qualitative information collected through semi-structured interview notes was analysed using a simple content summarising approach and qualitative content analysis techniques, with the intention of summing up the most relevant and interesting topics emerged from the interviews, mainly to guide the process of structured questionnaire design. The information collected through the structured farm survey was subject to descriptive statistical analyses as well as regression analyses. The dependent variable, willingness to participate in F2S, is assessed using three categorical (ordinal) variables, where the lowest value reveals a low level of willingness to participate in F2S programmes:

- I am willing to contribute as part of a group to supply directly with food products massive centres of consumption (schools, kindergarten, social care, etc.)
- I am willing to supply by myself with food products massive centres of consumption (schools, kindergarten, social care, etc.)
- I am willing to supply an intermediary to supply massive centres of consumption (schools, kindergarten, social care, etc.)

A Principal Component Analyses was used to create a composite variable from these three questions. The variable created is solid in terms of eigenvalue estimates, in this case higher than 1 (KMO = 0.621, sig = 0.000, percent of variance 60.064). Higher values imply higher level of willingness to participate. The coefficients of correlation between the dependent composite variable and its constituent variables are very high – 0.83, 0.82 and 0.67, respectively.

Considering the continual value of the dependent variable, a linear regression analyse was used to explore the relationships between the developed latent variables and farmers' willingness to engage in F2S programmes. Linear regression is a linear model, which assumes a linear relationship between the input variables (x) and the single output variable (y). The dependent variable, in this case, is the willingness to participate, is calculated from a linear combination of the input variables (x). Method of least-squares is used as a principal approach for fitting the regression line (Montgomery et al., 2021). This method calculates the best-fitting line for the observed data by minimising the sum of the squares of the vertical deviations from each data point to the line (if a point lies on the fitted line exactly, then its vertical deviation is 0). Because the deviations are first squared, then summed, there are no cancellations between positive and negative values.

To select the variables, a correlation matrix was used. Following the main findings of the literature review and the focus groups opinions, we selected a series of variables related to farm, farmer characteristics and behaviours. The model controls for socio-economic characteristic of the farmer such as education, experience in cultivating the main product and experience in emigration (as a proxy for professional experience gained elsewhere). Family farm characteristics are also used such as household size, land ownership, type of main product sold (greenhouse vegetables versus fruits). In addition, farmers' previous experience of being engaged in group actions (joint transportation activity), experienced level of losses (product post-harvest losses due to perishability and sales bottlenecks), promptness to cooperate with other farms or with local government, and level of information on food procurements (previously handled by the local government) and level of awareness of own product safety including as independent variables in the model. Table 3 presents the variables and each hypothesis direction.

Table 3: Definitions of variables included in the model, their operationalisation, and hypotheses

Independent Variable	Question	Operationalisation	Hypothesis direction
Age	Farmers age in no. of years	Scale variable expressed in number (of years)	+
Experience	No. of years cultivating the main product on the farm	Scale variable expressed in number (of years)	+
Education	Farmer's level of education	Categorised (ordinal) variable: 1. No education 2. Basic 3. Agriculture high school 4. Other high school 5. University	+
Land area	Total agriculture land area cultivated by the farm at present	Scale variable expressed in number (dynym)	+
Family size	No. of family members	Scale variable expressed in number (no of members)	+
Product type	The main product type (vegetables vs fruits)	Categorised variable 0 = Greenhouse vegetables and 1 = Fruits	+
Joint transportation activity	"Have there been times when you have transported the products together (in a group) to split costs?"	Categorised (ordinal) variable 1. Never 2. Rarely 3.Sometimes 4.Often 5.Always	+
Level of losses	The increased/decreased level of losses from the main product compared to the last season	Categorised (ordinal) variable 1. Much lower 2. Lower 3. About the same 4. Higher 5. A lot higher	+
Level of information availability/ absence	"I don't know how to apply for supplying kindergartens /hospitals."	Categorised variable 0 = False, 1 = True	-
Emigration experience	"Did you personally emigrate (abroad)?"	Categorised variable 1. Yes 2. No	+
Reliance on local government support	"Local government should support us on the demand about supplying kindergartens and schools."	Categorised (ordinal) variable 1. Strongly Disagree 2. Disagree 3. Neither Agree nor Disagree 4. Agree 5. Strongly Agree	+
Attitudes towards cooperating with each other	"We need to cooperate with each other to supply kindergartens and schools."		+
Selling uncertainty	"Uncertainty in selling the main product is a big problem."		+
Perceived health safety of own produce	"What is your perception about health safety of your farm products?"	Categorised (ordinal) variable 1. Very low 2. Low 3. So-So 4. High 5. Very high	+

Source: Own composition based on survey results

Results and Discussion

Farmers are usually not involved in supplying food products for large organisations and institutions mainly due to lack of information (Figure 2). Legal impediments such as the fiscal registration or inability to comply with standards are considered by farmers as valid reasons not to supply massive consumption units with their own farm produce.

Farmers are not accustomed to formal contracting. Results show that that only 2% of farmers have written contracts with their buyers (see Table 4). The majority, almost 79%, have informal agreements, while 29% are engaged in spot market exchange relationships. These findings are confirmed also by other value chain actors. Both intermediaries and catering companies argue that they cannot deal directly with farmers because they cannot provide fiscal receipts and are not willing to engage in long term, contractually regulated transactions.

The typology of relationships with buyers is illustrated in Figure 3. Only 37% of farmers have durable relationship which is instrumental to the supplier's evaluation. Since for a successful implementation of a F2S scheme, there is need for reliable and stable source of supply, farmers' exchange behaviours partially fit the required criteria.

Results also show that farmers engage mainly in selection and sorting of fruits and vegetables (52% of cases), while they rarely engage in cleaning and packaging (farmers responded they never do so in 45% and 93% of cases). Farmers are more prone to sorting-selection due to their labour availability, while the other operations are mainly performed

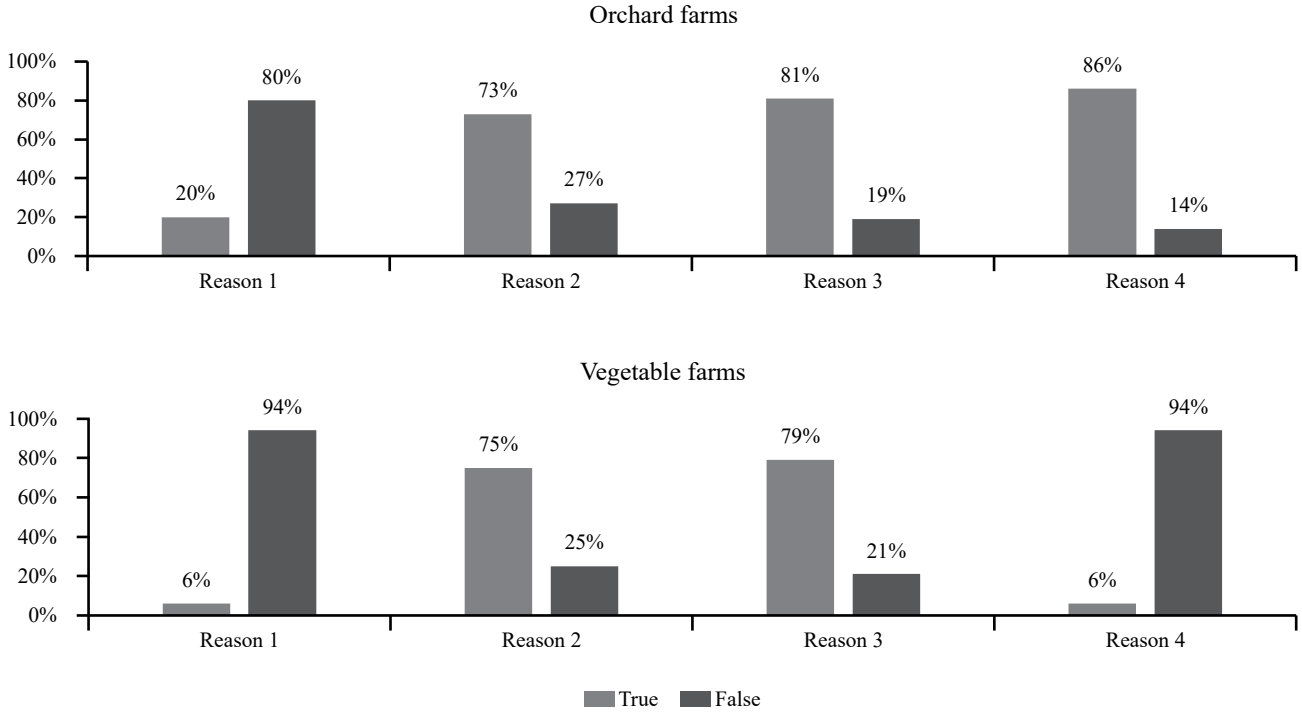

Figure 2: Reasons why farmers do not supply massive consumption units (MCU) with their products

Note: Reason 1: I don't have the fiscal farm ID number for selling (invoice number); Reason 2: I don't know how to apply for supplying kindergartens/hospitals; Reason 3: I don't have information on the specifications of products required for supplying kindergartens and hospitals; Reason 4: My products do not comply with the food and hygiene standards. Only the farmers who have not supplied MCU answered the questions. They could give more than one reason.

Source: Own composition based on survey results

Table 4: Type of agreements between farmers and buyers for two different sectors.

Sector	Type of agreement	Observations	Frequency
Orchards	Written contract	5	2%
	Verbal agreement	147	69%
	No agreement	62	29%
	Total	214	100%
Greenhouse vegetables	Written contract	70	25%
	Verbal agreement	157	57%
	No agreement	51	18%
	Total	278	100%

Source: Own composition based on survey results

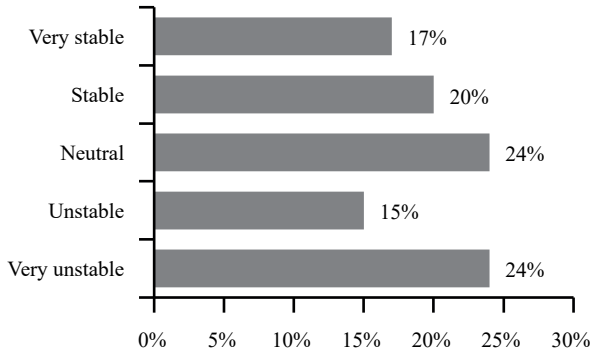

Figure 3: The stability of relationships between farmers and their buyers

Source: Own composition based on survey results

mainly based on capital investments. As previously noted, farmers have limited capacities to deliver food ready for consumption – only 46% possess their transport facilities. Even in the case of fruits to be sold directly to schools, the quality of delivery equipment is not adequate (Figure 4).

A majority of the farmers are informed about the potential of F2S to enable direct or intermediary-based sales to large buyers, namely public institutions. Our study reveals that farmers see large organisations such as schools, hospitals, and kindergartens as potential clients. Many see cooperation with other farmers as a solution to supply large volumes (36%), while larger farmers can supply these organisations by themselves (38%). However, around 52% of the respondents agree that this can be done through intermediaries (Figure 5).

A majority of the respondents are willing to supply through intermediaries. The ability of the farmers to sell individually or in group remains limited. One common issue hinges on the ability to invest in postharvest infrastructure. In recent years in Albania, a pivotal group of actors have been investing in postharvest logistics, the main driver of this being the export orientation experienced in the last decade, mainly in the greenhouse sector.

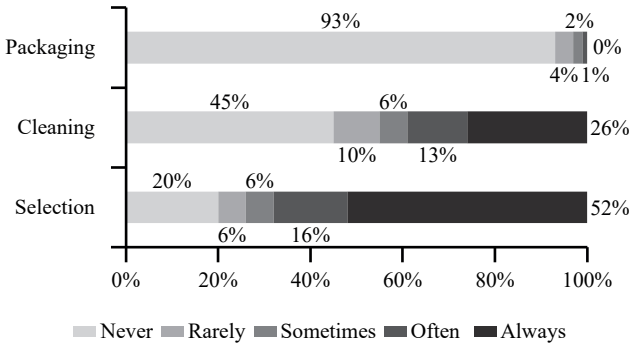

Figure 4: The extent of services like selection, cleaning and packing within farm for the main product

Source: Own composition based on survey results

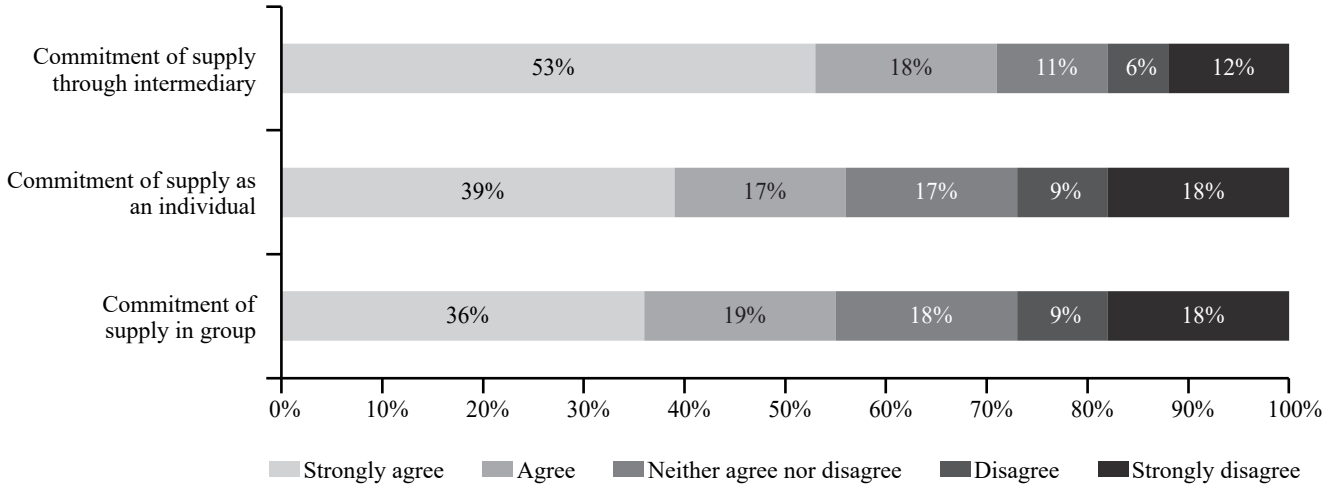

Figure 5: Willingness of farmers to supply massive consumption units with food products.

Source: Own composition based on survey results

Table 2: Linear regression results.

Model	Unstandardised Coefficients		Standardised Coefficients	t	Sig.
	Beta	Std. Error	Beta		
(Constant)	-3.642	.520	-	-6.998	.000
Age	.004	.003	.062	1.288	.199
Family size	-.020	.027	-.032	-.742	.458
Education	.055	.044	.057	1.238	.216
Experience	-.001	.006	-.011	-.233	.816
Land area	.009	.004	.125	2.677	.008
Product type (Fruits=1)	.021	.100	.011	.215	.830
Availability of information	.258	.099	.114	2.613	.009
Joint transportation activity	.097	.045	.093	2.157	.032
Reliance on local governmental support	.156	.056	.120	2.762	.006
Attitudes towards cooperation	.335	.043	.348	7.859	.000
Perceived safety of own produce	.110	.049	.094	2.223	.027
Post-harvest losses at farm level	.198	.054	.157	3.685	.000
Selling uncertainty	-.010	.050	-.009	-.205	.838
Emigration	-.136	.104	-.057	-1.303	.193

Dependent Variable: Willingness to participate; R=0.469 (F=9,049339, sig=0.000; DW=1.837

Source: Own composition based on survey results

According to the results, the average experience of farmers in the respective sectors is around 13 years, while the average total land area cultivated is 16.4 dynym with the average family size reaches 5 family members. For other descriptive statistics on the main variables in the model please refer to Appendix 1.

The results obtained from the linear regression model are presented in Table 6. Farm characteristics such as cultivated agriculture land area and the level of post-harvest losses are positively associated with the farmers' willingness to be engaged in F2S schemes. Farmers' previous experiences in joint transportation activity are a positive factor for the willingness to be engaged in F2S schemes. Results show that the higher the perceived safety of a farmer's own produce, the higher is the likelihood to be willing to engage in F2S schemes. Absence of information on school and kindergarten food procurements is a factor negatively associated with farmers willingness to participate in F2S schemes. As hypothesised, reliance on local governmental support and positive attitudes towards cooperation positively affect farmers willingness to take part in F2S programmes.

Results show that, selling uncertainties and type of product turned out not to be statistically significant factors in farmers' willingness to participate in F2S programmes. Moreover, post-harvest losses are positively associated with the farmers willingness to be engaged in F2S schemes. Considering the recent concerns on oversupply in the internal market, the farmers perceive that entering a F2S scheme is an exit option for addressing market losses. An increasing share of losses, especially in orchard farms in the future, is a potential motivation to make farmers engage into F2S schemes. Contrary to our hypotheses, farmers' uncertainty on sales is not statistically significant. In contrast to the findings of Gërdoci *et al.* (2017), increased uncertainty is not related to the likelihood of farmers establishing sustainable (lasting) relationships with buyers. This might be the case also because a large number of farmers do not perceive F2S programmes to be "lengthy market" relations. Previous studies have confirmed that farmers who are engaged in contract farming or long-term relations with buyers experience lower post-harvest losses (Imami *et al.,* 2013). Considering this variable as an economic motivation, similarly to other authors (Hinrichs, 2000; Izumi, 2010; Conner *et al.,* 2012; Matts *et al.,* 2016; Nathan Rosenberg *et al.,* 2014), the study shows that economic based motivations are very important.

Farmers' previous experiences in joint transportation activity positively affects their willingness to engage in food provision to schools. The result might be related to farmers' proactiveness towards carrying out joint activities. Indeed, farmers' cooperation is positively associated with the willingness to provide food to schools. In a finding similar to that of Izumi *et al.* (2010), the results show that the higher the perceived health safety of own produce, the higher the willingness to engage in school food provision. The reasoning is that farmers who are aware of their product safety superiority are more prone to participate in F2S supply schemes. Given that major contractual failures are known to happen related to safety and traceability, farmers are increasingly aware of the need to achieve safety standards.

The absence of information on school and kindergarten food procurements is a factor negatively associated with farmers' willingness to participate in F2S schemes. Due to missing or limited information, farmers, as shown by Gerdoci *et al.* (2017), are risk averse. Taking the legal and other specific criteria into account, farmers who are familiar with the requests are not likely to join a F2S programme as they believe they cannot satisfy what they perceive to be conditions (e.g. ability to fulfil procurement needs in time, formalisation requirements, analyses of products and following quality protocols).

Given the information gap and the lack of prior experiences, farmers' willingness to participate in F2S is still influenced by the perceived role of – and their reliance on – local governmental support. The results provide evidence for the increasing role of local government as a bridge (Bagdonis *et al.,* 2009) to F2S programmes. As has also previously been explained by Thompson *et al.* (2014), in countries where smallholders make up most of the farming community, appropriate local level agriculture infrastructure and services are very important for fostering smallholder farmers integration in F2S programmes. The size of farms makes cooperation more important when considering coordinated actions in the scheme. This aspect is related to the awareness of the farmers regarding the reduced possibility to sell small quantities. Therefore, it seems that in contrast to the findings of Morakile *et al.* (2021), Albanian farmers do still value collective action to exploit options emerging from school feeding.

As expected, farm characteristics such as cultivated agriculture land area are positively associated with farmers' willingness to be engaged in F2S supply, a finding largely in line with Matts *et al.* (2016). In Albania, due to the high fragmentation of land, farm size remains crucial for creating viable food provision and sufficient quantity for procurement. The human resources at farm level (farm size) have no statistically significant relationship with the willingness to participate in F2S supply due to a larger engagement of rented labour in the specialised farms.

Surprisingly, the type of product is a factor that is not related in a statistically significant way to farmers' willingness to participate in F2S schemes. On the supply side, the level of post-harvest losses and perishability does not significantly differ between product types. On the demand side, the lack of any significant relationship may be due to the absence of previous procurements from these farms and a lack of direct market signals resulting in a relationship centring on supplying farm produce to schools and kindergartens. Results show that farmer experiences, education and emigration background are not statistically significant. The reason for this may be that a farmer's willingness to participate in F2S is attributable primarily not to their level of experience, but rather to the level of risk they perceive it has.

Conclusions

Integration of local food producers into F2S supply schemes contributes to multiple objectives, but also provides small and local farms with an additional or alternative trade channel for their products. An assessment of willingness to

participate in F2S is crucial to achieving a feasible programme implementation. The purpose of this paper is to model farmers' willingness to participate in F2S programmes and analyse factors that will affect farmers' participation decisions.

Economic factors intertwined with social capital factors and attitudinal indicators affect farmers' willingness to participate in coordinated food supply chains as in the case of F2S schemes. Land area (farm size) and post-harvest losses at farm level used as economic reasons, justify farmers willingness to participate in F2S significantly. Additionally, level of access to information about these schemes, prior experience with joint activities and reliance in local governmental support used as social capital indicators influence farmers' willingness to engage in F2S, an influence that is reinforced also by the positive attitudes towards cooperation and the perceived safety of own produce.

Although smallholders are not ready to supply food catering supply chains directly, they are willing to be part of a F2S scheme through group provision or through brokerage. The results indicate the importance of identifying and involving the proper range of suppliers when formulating the procurement procedures and the eligibility as well as premium criteria for selection of suppliers. Thus, farmers experiences, opinions and perceptions provide entry points for establishing the F2S programme.

The government should raise awareness and provide know-how on F2S scheme requirements, provide best examples of organisation in groups through common contracts and increase the financial capacity for achieving compliance in terms of food safety and quality. Contract farming should be introduced to increase the capacities and tackle the exclusion of inexperienced farmers. The availability of service providers (i.e. facilities in common use, or companies which provide post-harvest and first processing services in return for a fee), at local government level can also facilitate a larger involvement of small farmers and processors into complex F2S supply chains.

Further research should be carried out to explore other actors' behaviour in the value chain. It needs to be taken into account that the institutional environment for the functioning of a F2S scheme is based also on intentions and actions of other actors in the value chain. The most important of these are the consolidators and intermediaries who assemble the large flows and are those contracted for the procurement. This may be the usual situation in cases where the majority of farmers are smallholders and where there are no incentives for cooperation. Improving preconditions for collective action in post-communist transition country agriculture is critically important for F2S programmes. Supporting cooperation through capacity building together with the easier legal procedures is a precondition for the success of F2S. Here the issue is to understand the transaction costs and the factors making consolidators and intermediaries interested in being integrated into F2S programmes. An additional important actor is the local government or the school. Depending on the legal form, the municipality would be the institution responsible for the procurement of food. Their eagerness to identify and activate local resources has both benefits and challenges. Consequently, there is a need to explore both the costs and benefits using participatory analysis.

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Appendix

Appendix 1: Descriptive statistics of the variables.

Independent Variable	**Categories and respective frequencies**				
Product type	Vegetable			Fruits	
	56.5%			43.5%	
Education level	No education	Basic	Agriculture high school	Other high school	University
	0.2%	52.2%	18.3%	20.3%	8.9%
Prior joint transportation activity	Never	Rarely	Sometimes	Often	Always
	74%	11%	9%	4%	2%
Level of post-harvest losses	Much lower	Lower	About the same	Higher	A lot higher
	1%	19%	47%	30%	3%
Availability/absence of information	True			False	
	74%			26%	
Emigration	Yes			No	
	78%			22%	
Perception on health safety of own produce	Very low	Low	So-so	High	Very high
	0%	1%	10%	27%	62%
	Strongly disagree	**Disagree**	**Neither agree nor disagree**	**Agree**	**Strongly agree**
Reliance on local governmental support	1%	3%	5%	34%	57%
Attitudes towards cooperation	3,9%	6,4%	15,5%	40,5%	33,7%
Selling uncertainty	2%	3%	6%	29%	60%

Source: Own composition based on survey results

Jasper GRASHUIS* and Ye SU**

Farmer-owned brand purchases: The importance of label comprehension and price fairness perception

The farmer-owned label is a relatively recent addition to the crowded landscape of information on food and drink product packages. Due to its novelty, research on the farmer-owned label is still scarce. Using 451 responses from random food consumers in the United States, we attempt to explain variability in the purchase of farmer-owned brands in ten different food and drink product categories in terms of label comprehension and price fairness perception. Our structural equation model results are contrary to expectations: we find a negative relationship of label comprehension to the farmer-owned brand share, which implies food consumers do not support the various implications of farmer ownership of food brands. In addition, respondents who perceive more distributive price fairness and procedural price fairness purchase a higher proportion of farmer-owned brands. Implications for researchers, practitioners, and policymakers are discussed.

Keywords: farmer-owned, agricultural cooperative, consumer behaviour, label comprehension, price fairness, structural equation model

JEL classifications: D91; L66; Q12

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Introduction

Food producers and marketers convey increasingly more information to consumers about the presence or absence of certain product and process attributes by means of logos, labels, and other mechanisms. Theoretically, such mechanisms reduce the level of information asymmetry between producers and consumers and thus limit market imperfections. Some of the many examples relate to organic production (Chekima *et al.,* 2019), genetic modification (Grebitus and Van Loo, 2022), product origin (Grashuis and Su, 2022), and traceability (Liu *et al.,* 2019).

A relatively new label is the farmer-owned label. At its essence, the farmer-owned label constitutes an information signal regarding the ownership of the brand: the brand is (collectively) owned and managed by farmers who are members of cooperatives or similar organisations. While there are approximately 2,000 cooperatives in the United States (U.S. Department of Agriculture, 2021), relatively few have brand equity as indicated by trademarks (Hardesty, 2005; Grashuis, 2017). Even fewer cooperatives use the farmer-owned label to complement any brand equity.

The farmer-owned label also has deeper implications, particularly in terms of who supplies the ingredients and who captures the profits. In cooperatives, farmers have dual roles as suppliers or customers and investors (Limnios *et al.,* 2018); by contrast, shareholders of corporations are generally only investors and not suppliers or customers of the business organisation. To be specific, farmers who are members of marketing cooperatives invest equity and also sell output (e.g. corn, milk, cotton) to the business organisation. Generally, farm-gate prices are higher for farmers who are members of marketing cooperatives (Jardine *et al.,* 2014; Grashuis, 2020).

The farmer-owned label is related to other labels and similar mechanisms in the consumer marketplace. Arguably the best comparison is facilitated by the Geographic Indication (GI) and the Protected Designation of Origin (PDO). The motivation behind GIs and PDOs is to provide a communication signal for consumers and to generate a positive return for farmers (Bellassen *et al.,* 2022). Thus, even though the direct connotation of GIs and PDOs is the origin of the product (e.g. Gorgonzola cheese, Irish whiskey, Orkney lamb), the underlying premise is to reward farmer investment. According to Hayes *et al.* (2004), farmer-owned brands form a subset of GIs.

Empirical evidence of the effect of the farmer-owned label is mixed (Grashuis, 2021). One possible explanation for the mixed findings is label comprehension. In one of the few studies on the farmer-owned label, Grashuis (2021) conducted a framed choice experiment with Dutch milk consumers and only estimated a significant price premium if information about the profit allocation to farmers as opposed to investors is disclosed. The result highlights a possible lack of comprehension on the part of consumers who are not informed or educated in terms of the farmer-owned label. In the broader literature, label comprehension has been identified as an important driver of consumer behaviour (McEachern and Warnaby, 2008; Grimes *et al.,* 2009).

Hypothesis 1: Comprehension of the farmer-owned label is positively associated with the purchase of farmer-owned brands

Another overlooked factor with potential to explain the mixed evidence of the farmer-owned label is fairness. Fairness in general and price fairness in particular have been of recent and current interest to the agri-food industry (Hendrickson and James, 2016). Concerns with fairness stem from increases in market concentration at the downstream stage of the value chain. Due to mergers and acquisitions, there are increasingly fewer processors and retailers, with potentially adverse consequences for transparency in contracts and spot market transactions with farmers. Food consumers with other-regarding preferences may gain utility from allocating more profit to farmers than other agents

in the value chain (Briggeman and Lusk, 2011; Busch and Spiller, 2016; Samoggia *et al.,* 2021). The same type of food consumers may therefore support the farmer-owned label and its various implications.

Hypothesis 2: Consumers with price fairness preferences are more likely to purchase farmer-owned brands

Taking the above into consideration, we build on prior research by Grashuis (2021) with an empirical study of consumer behaviour in the context of farmer-owned brands in ten food and drink product categories. However, unlike Grashuis (2021), we do not study revealed consumer preferences for product or process characteristics in an experimental setting; instead, like Tandon *et al.* (2020) and Segovia *et al.* (2022), we assume a behavioural perspective via the consideration of consumer psychographic characteristics to help explain variability in stated preferences. Specifically, we address the question if it is possible to explain variability in the consumer choice of farmer-owned brands in terms of label comprehension and price fairness perception? Put differently, are consumers who comprehend the farmer-owned label more likely to choose farmer-owned brands? And are consumers who perceive price unfairness in the agri-food value chain also more likely to choose farmer-owned brands?

We address the above questions using survey responses from 451 food consumers in the United States. We explain variability in the purchase of farmer-owned brands at the consumer level by building a structural equation model with label comprehension and price fairness perception as latent predictors. Our novel findings are surprising. Generally, respondents who perceive more price fairness in the agri-food value chain are more likely to purchase farmer-owned brands. Also, respondents who have a superior comprehension of farmer-owned label implications are less likely to purchase farmer-owned brands. We thus address a substantial gap in the empirical literature on the importance of psychographic characteristics to the purchase of farmer-owned brands. There are several implications for researchers, practitioners, and policymakers, which are further discussed in the conclusion.

Food Consumer Survey

In April of 2022, we conducted an online survey on Qualtrics. To avoid variability in brand availability across regions, we limited the geographic pool of the respondents to the Midwest region of the United States. Food and drink brands in the Midwest region may not be available in, for example, the Northeast region, and vice versa. Another motivation for the Midwest region is the location of the research team. The respondents also needed to meet three other criteria: (1) to be at least 18 years of age, (2) to be the primary grocery shopper in their household, and (3) to have consumed at least one of the following ten food or drink products within the prior three-month period: almond milk, apple juice, butter, cheese, cranberry juice, milk, orange juice, organic milk, raisins, or rice. We selected these product categories because of the presence of farmer-owned brands. We received a total of 465 responses to the online survey. We dropped eight respondents who failed an attention check as well as six respondents with missing data, thus reducing the sample size to 451.

The survey consisted of four parts: (1) demographic information, (2) comprehension of the farmer-owned label, (3) perception of price fairness in the agri-food value chain, and (4) purchase of farmer-owned brands in the ten product categories. We report the summary statistics of the demographic characteristics of our sample in Table 1.

Table 1: Demographic Characteristics of the Sample.

Variable	Mean	Standard Deviation
Age: 18-24	0.03	0.17
Age: 25-34	0.47	0.50
Age: 35-44	0.28	0.45
Age: 45-54	0.14	0.34
Age: 55-64	0.05	0.22
Age: 65 or older	0.03	0.17
Gender: Female	0.47	0.50
Education: High school or less	0.08	0.28
Education: 2-year college degree	0.09	0.28
Education: 4-year college degree	0.61	0.49
Education: Advanced college degree	0.22	0.42
Income (x1000)	63.07	22.75
State: Illinois	0.15	0.36
State: Indiana	0.29	0.46
State: Iowa	0.03	0.17
State: Kansas	0.04	0.21
State: Michigan	0.10	0.31
State: Minnesota	0.04	0.20
State: Missouri	0.10	0.30
State: Nebraska	0.01	0.08
State: North Dakota	0.02	0.12
State: Ohio	0.15	0.36
State: South Dakota	0.01	0.08
State: Wisconsin	0.05	0.22

Source: Own composition

Overall, the average respondent is relatively young (50% are 34 years of age or younger) and educated (83% have a four-year college degree or higher). While the sample is not necessarily reflective of the overall population, these respondents are all grocery shoppers who make purchase decisions and brand choices and are therefore of interest to the study.

To inform consumer comprehension of the farmer-owned label, we showed respondents four generic statements about ownership, governance, supply source, and profit allocation implications (see Table 2). Each statement featured a correct option, an incorrect option, and an “I don’t know” option. The four generic statements are not based on an existing instrument, which to our knowledge is not available in the

Table 2: Farmer-Owned Label Comprehension.

Statement	Percentage
Ownership	
The brand is owned by farmers	0.84
The brand is owned by investors	0.14
I don't know	0.02
Governance	
Farmers make business decisions about the brand	0.79
Farmers do not make business decisions about the brand	0.16
I don't know	0.05
Supply Source	
The ingredients used in the product come from the owners of the brand	0.60
The ingredients used in the product come from independent suppliers	0.33
I don't know	0.07
Profit Allocation	
A higher percentage of the price goes to farmers	0.68
A lower percentage of the price goes to farmers	0.26
I don't know	0.06

Source: Own composition

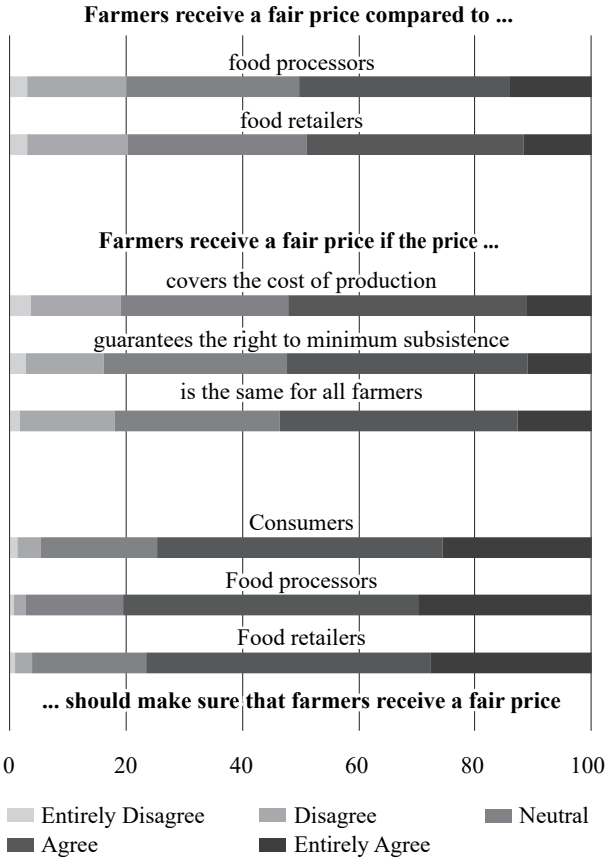

Figure 1: Consumer Perceptions of Distributive, Procedural, and Interactional Price Fairness.
Source: Own composition

literature. To avoid order bias, we randomized the order of the correct option and the incorrect option; the "I don't know option" always appeared last.

The average respondent has a relatively strong comprehension of the basic implications of the farmer-owned label. On average, 84% and 79% know the brand is owned and managed by farmers as opposed to investors, respectively. However, without additional information, fewer respondents grasp the deeper implications of the farmer-owned label. Sixty percent of the respondents identify the correct source of the product ingredients as farmers, while 68% of the respondents know a higher percentage of the price is allocated to farmers as opposed to investors.

Following Busch and Spiller (2016), we estimated the price fairness perceptions of respondents in the context of the overall agri-food value chain. Our approach also relates to Gielissen and Graafland (2009) and Samoggia *et al.* (2021), who measured price fairness perceptions in the coffee and processed tomato sectors, respectively. Like Samoggia *et al.* (2021), we also considered three different components of price fairness: (1) distributive fairness, which concerns the relative profit allocation among buyers and sellers, (2) procedural fairness, which relates to the price-setting procedure of the sellers, and (3) interactional fairness, which considers the honesty and transparency of the sellers (Samoggia *et al.,* 2021). We informed each component with two to three five-point Likert statements with "entirely disagree" and "entirely agree" as the anchors (see Figure 1). All the statements have been adapted from Gielissen and Graafland (2009), Busch and Spiller (2016), and Samoggia *et al.* (2021). According to the data, approximately 50% of the respondents agree that farmers receive a fair price compared to food processors and food retailers, which concerns the construct of distributive price fairness. Like Busch and Spiller (2016) and Samoggia *et al.* (2021), we thus observe a substantial number of respondents who think price distributions in the agri-food value chain are not fair. On average, respondents agree more with the three statements in relation to the construct of procedural price fairness. Considering the similarity in the distributions, all three statements appear to approximate the concept of procedural price fairness to the same degree. The distribution is further skewed to the left in terms of interactional price fairness as approximately 80% of the respondents agree that other parties in the agri-food value chain (i.e. consumers, food processors, food retailers) bear some responsibility for farm-gate prices.

For respondents who indicated to have purchased a given food or drink product within the prior three-month period, we also asked about the selected brand. Among the five options we showed one farmer-owned brand, two name brands, as well as "store brand" and "other". As reported in Figure 2, the overall share of the farmer-owned brand varies across the ten product categories. The share is the largest in the almond milk and the cranberry juice categories, and the smallest in the cheese category. Most of the competition is derived from other name brands as store brands have a relatively small share ranging from four percent (organic milk product category) to 20 percent (milk product category).

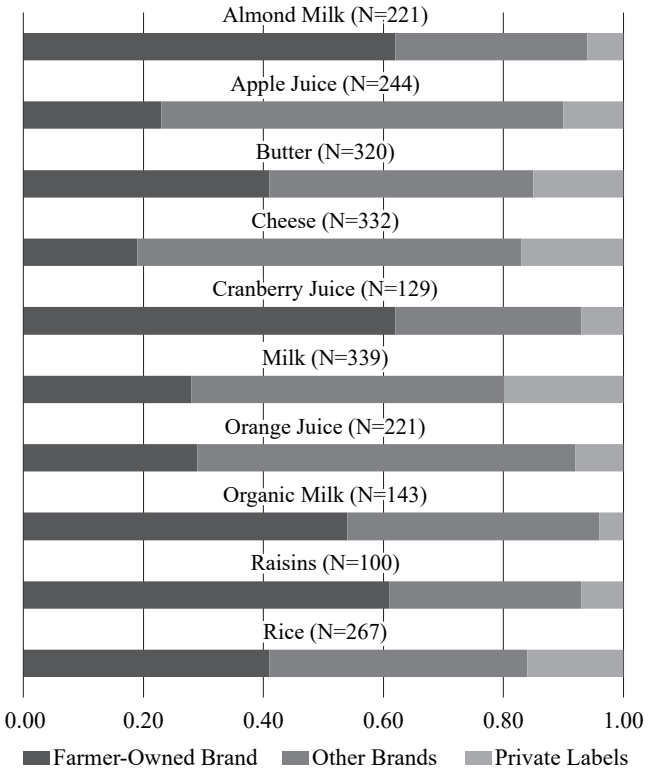

Figure 2: Farmer-Owned Brand Share Across Product Categories.
Source: Own composition

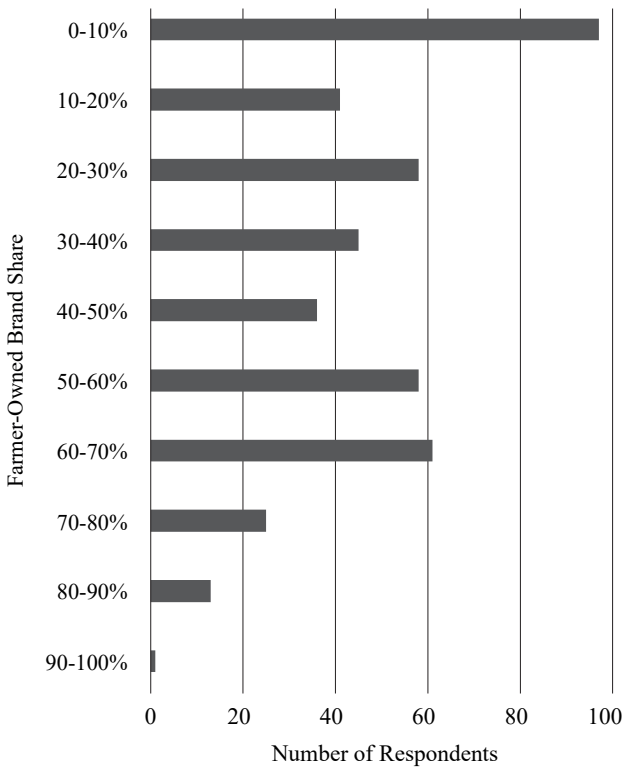

Figure 3: Distribution of the Farmer-Owned Brand Share.
Source: Own composition

For each respondent, the farmer-owned brand share at the individual level is calculated as the ratio of the number of purchased farmer-owned brands to the number of purchased food and drink products. The share ranges from zero to one, where zero indicates that the respondent purchased no farmer-owned brands, and one indicates that the respondent only purchased farmer-owned brands. For example, if a respondent purchased five of the listed food and drink products in the prior three-month period and two of the five came from a farmer-owned brand, then the farmer-owned brand share for the individual is 0.40. Across the full sample and all ten product categories, the mean share of the farmer-owned brand is 0.36. Furthermore, as depicted in Figure 3, the distribution is non-normal with a right skew as a relatively large proportion of respondents do not purchase any farmer-owned brands.

Structural Equation Model of Farmer-Owned Brand Share

With label comprehension, distributive price fairness, procedural price fairness, and interactional price fairness as latent constructs, we use the structural equation modelling (SEM) method to explore the statistical relationships. SEM has a long history in the field of social sciences (Tarka, 2018). Increasingly more economists in the field of agricultural and food economics use the method to involve behavioural science elements (Grashuis and Cook, 2021; Tong *et al.,* 2021). SEM involves the analysis of covariances and correlations to test statistical relationships by combining the various characteristics of exploratory factor analysis or confirmatory factor analysis as well as multiple regression (Ullman, 2001; Bollen and Pearl, 2013). A typical structural equation model has two components: (i) the measurement model, which contains the relationships between the latent variables and its manifest variables, and (ii) the structural model, which contains the relationships between the latent variables.

Following Jöreskog (1970), the structural model is given by

$$\eta = B\eta + \Gamma\xi + \zeta \tag{1}$$

where, if q is the number of outcome variables and r is the number of predictors, η is the $q\ x\ 1$ vector of endogenous latent variables (i.e. outcome variables), ξ is the $r\ x\ 1$ vector of exogenous latent variables (i.e. predictors), and ζ is the latent stochastic term. B and Γ are the $q\ x\ q$ and $q\ x\ r$ vectors of parameters for the endogenous and exogenous latent variables, respectively. There is one equation for each outcome variable in the structural model. The measurement model is defined as

$$y = \Lambda_y\eta + \epsilon \tag{2}$$

and

$$x = \Lambda_x\xi + \delta \tag{3}$$

where x is the vector of manifest variables in relation to the exogenous latent variables, y is the vector of manifest variables for the endogenous latent variables, Λ is the vector of

random parameters to be estimated, and δ and ε are the stochastic terms for x and y, respectively. Our base structural equation model is illustrated in Appendix 1 and estimated in Stata 17 using the sem command. Correspondingly, Table 3 also lists all the model variables, which are the four latent variables (i.e. distributive price fairness, procedural price fairness, interactional price fairness, label comprehension), their manifest variables, and the outcome variable (i.e. farmer-owned brand share).

Results and Discussion

We report the results of the base structural equation model in Appendix 2. The coefficients (i.e. path loadings) are standardised to facilitate easy interpretation of the statistical relationships. The coefficients thus indicate how many standard deviations the outcome variable increases or decreases with a one-unit (i.e. standard deviation) change in the predictor.

Farmer-Owned Label Comprehension

Label comprehension is negatively related to the farmer-owned brand share. An increase of one standard deviation in label comprehension is estimated to decrease the farmer-owned brand share by 0.235 standard deviations. To be clear, respondents who better understand the various implications of the farmer-owned label have a significantly lower farmer-owned brand share, which is contrary to Hypothesis 1. There are several considerations. First, respondents do not appear to accept or support the underlying implications of the farmer-owned label. If the implications form a deterrent as opposed to a stimulant to the purchase of farmer-owned brands, then the very foundation of the farmer-owned label should be called into question. Second, when examining the loadings of the four manifest variables to the latent construct of label comprehension, the largest magnitude is observed for the price implication (i.e. a higher percentage of the price goes to farmers), followed by the ownership implication (i.e. the brand is owned by farmers) and the governance implication (i.e. farmers make business decisions about the brand). As such, the result is driven by the price implication, which serves as the main objective behind the farmer-owned label. Third, on the positive side, the farmer-owned label is not the only product or process attribute of relevance to the purchase decisions of food consumers. Price, quality, taste, and other attributes may also explain variability in the farmer-owned share. As such, the latent construct of label comprehension should be tested in a controlled experiment with other attributes to better isolate its effect and prevent any upward or downward bias.

The result regarding the negative relationship of label comprehension to the farmer-owned brand share relates to Grashuis (2021), who failed to find a significant price premium for the farmer-owned label in the absence of additional information in terms of the payoff distributions to farmers as opposed to investors. Grashuis (2021) recommended education to increase label comprehension, and the same applies here. Arguably the best solution is for some umbrella organisation, such as an industry-level union or council representing farm producer organisations, to make a collective investment in an information or communication campaign to improve the comprehension of the farmer-owned label and its various implications. As price fairness in the agri-food value chain is of relevance to overall society, policymakers may also help address the situation by educating the public about the farmer-owned label.

Table 3: Overview of Structural Equation Model Variables.

Variable	Measurement Scale	Variable Type
x1	1-5	Manifest Variable
x2	1-5	Manifest Variable
x3	1-5	Manifest Variable
x4	1-5	Manifest Variable
x5	1-5	Manifest Variable
x6	1-5	Manifest Variable
x7	1-5	Manifest Variable
x8	1-5	Manifest Variable
x9	1-2	Manifest Variable
x10	1-2	Manifest Variable
x11	1-2	Manifest Variable
x12	1-2	Manifest Variable
Distributive Price Fairness		Latent Variable
Procedural Price Fairness		Latent Variable
Interactional Price Fairness		Latent Variable
Label Comprehension		Latent Variable
Farmer-Owned Brand Share	0-1	Outcome Variable

Source: Own composition

Price Fairness Perception

According to the results, the latent constructs of distributive price fairness and procedural price fairness both have significant and positive relationships to the farmer-owned brand share, which is evidence in favour of Hypothesis 2. All else equal, respondents who have a more positive perception of distributive price fairness purchase a higher proportion of farmer-owned brands. A one standard deviation increase in the latent construct of distributive price fairness is associated with a 0.351 standard deviation increase in the farmer-owned brand proportion. The estimated effect of the latent construct of procedural price fairness on the farmer-owned brand share is larger at 0.412 standard deviations. The higher the perceived fairness in terms of the price-setting procedures of the buyers in the agri-food value chain, the greater the farmer-owned brand share. Both estimates come as a surprise if the farmer-owned label is assumed to be a response to unfair farm-gate prices.

The relationship of the latent construct of interactional price fairness to the farmer-owned brand share is not significantly different from zero. While the three statements which act as the manifest variables of interactional price fairness commanded the most agreement among respondents, it is unable to significantly explain variability in the farmer-owned brand share. Therefore, respondents with lower or higher degrees of agreement in terms of interactional price fairness do not have significantly different farmer-owned brand shares. The lack of a significant relationship is surprising as interactional price fairness is in part determined by the perceived responsibility of consumers to ensure fair farm-gate prices. However, respondents who feel more responsible do not have a significantly higher farmer-owned brand share than respondents who feel less responsible.

Model Fitness and Improvement

An inherent objective of the SEM method is the pursuit of good fit to the data. As reported in Table 4, the goodness-of-fit statistics of our structural equation model do not meet the criteria recommended in the literature (Schreiber *et al.,* 2006; Hooper *et al.,* 2008; Kline, 2015). Therefore, in the interest of conformity, it is necessary to specify a more parsimonious model with fewer variables and fewer relationships. At the same time, other covariances and correlations must be considered if statistically significant.

Table 4: Goodness-of-Fit of the Structural Equation Model.

	Base Model		Final Model	
	Model Statistic	**Guideline**	**Model Statistic**	**Guideline**
X2	894.098		57.379	
p > X2	0.000	<= 0.05	0.000	<= 0.05
RMSEA	0.082	<= 0.07	0.062	<= 0.07
CFI	0.707	>= 0.95	0.975	>= 0.95
TLI	0.665	>= 0.95	0.946	>= 0.95

Source: Own composition

The final model, which conforms to the definitions of good fitness (see Table 4), is based on three changes to the base model: (1) the nonsignificant relationship of the latent construct of interactional price fairness to the farmer-owned brand share is removed; (2) the latent construct of label comprehension is only manifested by one variable (i.e. a higher percentage of the price is allocated to farmers as opposed to investors); (3) the latent constructs of procedural price fairness and interactional price fairness are manifested in part by the same variables. Appendix 3 displays the final model, for which there are three key takeaways. First, the estimated path loadings in the structural model are almost identical in the final model as compared to the base model. Second, the latent construct of label comprehension only explains a relatively small amount of the variance in the farmer-owned brand share. Third, the three different components of price fairness (i.e. distribute price fairness, procedural price fairness, interactional price fairness) are not independent of one another.

Summary and Conclusions

We conducted a survey in order to analyse consumer behaviour in the context of farmer-owned brands. The survey elicited information about the comprehension of the farmer-owned label and the perception of price fairness in the agri-food value chain, which we used in a structural equation model to help explain variability in the purchase of farmer-owned brands in ten food and drink product categories. According to the results, label comprehension is related negatively to the purchase of farmer-owned brands, which implies the various implications of the farmer-owned label (i.e. increased profit allocation to farmers as opposed to investors) are not supported by the average consumer. Also, distributive price fairness and procedural price fairness have a positive relationship to the purchase of farmer-owned brands, which raises questions about the direction of causality.

Our findings have several implications. For researchers, our scale of price fairness is applicable in other studies of the agri-food value chain. Using material from various publications, the three separate components (i.e. distributive price fairness, procedural price fairness, and interactional price fairness) all have strong internal consistency; the manifest variables all load significantly on the latent constructs. For practitioners, there is reason to be concerned about the very foundation of the farmer-owned label. Food consumers may not support the main implication of farmer ownership, which concerns the increased allocation of profit to farmers as opposed to investors. At the very least, consideration ought to be given to further decreasing the asymmetry of information between producers and consumers, many of whom do not comprehend the deeper implications of the farmer-owned label. For policymakers, there is also an opportunity to become engaged in the education of the public regarding farmer ownership or participation in the downstream stage of the agri-food value chain. For example, policy may address the current deficit of attention afforded to agricultural cooperatives and similar initiatives in high school curricula.

We note several weaknesses and limitations to inform future research directions. First, we explained variability in the farmer-owned brand share in terms of two consumer psychographic characteristics (i.e. price fairness perception, label comprehension). However, brand choice is determined by many other variables such as price sensitivity, risk preference, and brand loyalty. More research is necessary to inform the true relationship of price fairness perception and label comprehension to the farmer-owned brand share while controlling for the effect of other possible determinants. Second, we showed respondents a series of eight statements to inform price fairness and a series of four statements to inform label comprehension. While the measurement model showed a good fit to the data, there may exist other statements with a superior capacity to manifest the latent constructs. Also, instead of a predetermined set of statements, fewer restrictions may allow respondents to better inform latent constructs. For example, a free word association task may yield a better insight into price fairness perception and label comprehension. Third, we estimated a pooled structural equation model by aggregating the purchases of farmer-owned brands in ten different food and drink product categories. However, there is much heterogeneity across the ten product categories in terms of brands, competitors, prices, and other product and process attributes. In addition, consumers may behave differently across the ten product categories. Therefore, a dedicated model for each product category may yield different results as to the relationships of label comprehension and price fairness perception to the farmer-owned brand share.

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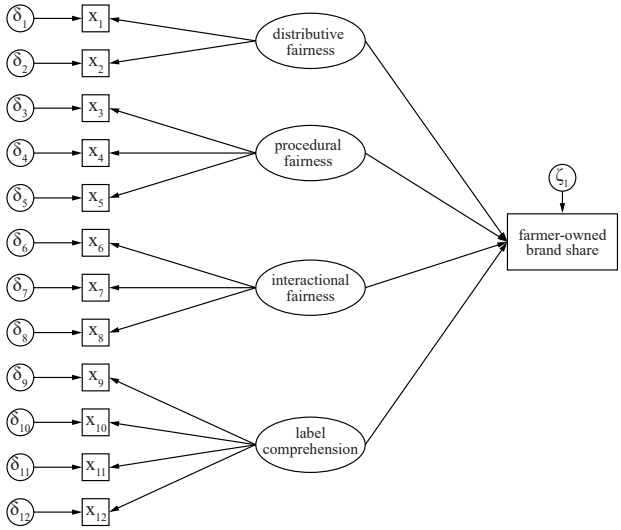
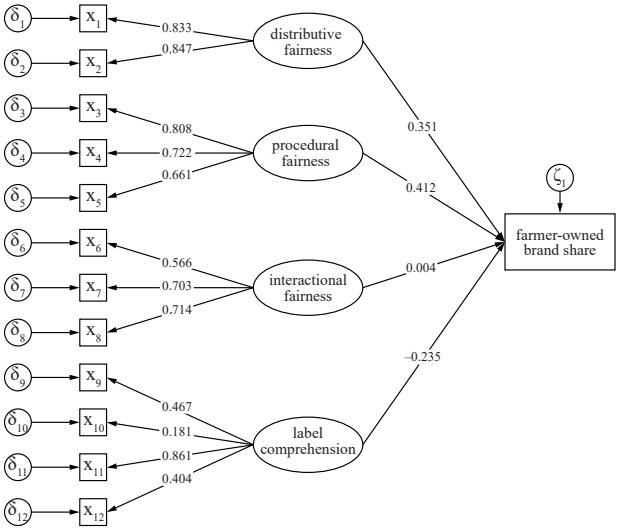
Appendix

Appendix 1: Hypothesised Structural Equation Model.



Source: Own composition

Appendix 2: Results of the Base Structural Equation Model.



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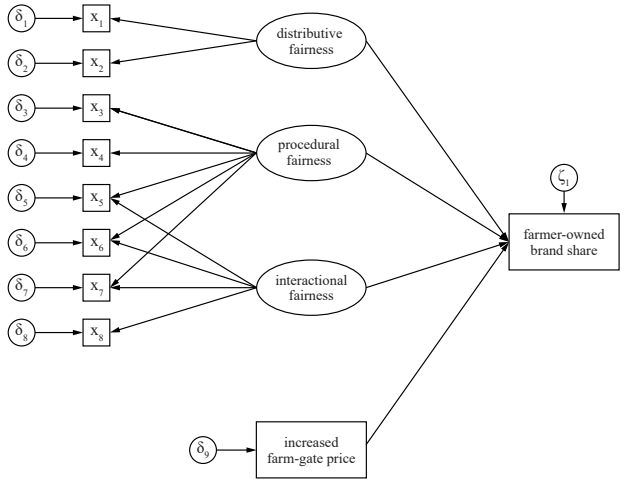
Appendix 3: Results of the Final Structural Equation Model.



Source: Own composition

Qi DONG*

Comparing Technical and Allocative Efficiency between Family Farms and Agricultural Corporations: Evidence From Japan's Rice Sector

Is an agricultural corporation more efficient than a traditional family farm? This paper attempts to answer this question by examining the technical and allocative efficiency of family farms and agricultural corporations. To do so, it applies the stochastic production frontier method in panel data built on the family farms and agricultural corporations in the Japanese rice sector and focuses on comparing the technical and allocative efficiency of the two production forms at the same scale of operation. Results reveal that family farms have a significant advantage over agricultural corporations in technical efficiency at each level of scale of operation. In both production forms, as the scale of operation increases, the technical efficiency correspondingly rises. However, the disparity in technical efficiency diminishes between the two production forms as their land size increases. In contrast, the allocative efficiency of different factors differs between family farms and agricultural corporations at different scales of land size. Overall, family farms show superiority in the allocative efficiency of labour, and agricultural corporations exhibit superiority in the allocative efficiency of agricultural capital. Last, decomposition of total productivity progress (TFP) reveals that family farms have positive TFP change which is mainly attributable to a positive and large allocative component, while agricultural corporations undergo negative TFP change due to its negative and large allocative component. Moreover, the results intimate that technical progress and technical efficiency improvement are faster in agricultural corporations than in family farms.

Keywords: Agricultural corporation, family farm, technical efficiency, allocative efficiency
JEL classifications: D10, D22, D24, Q10

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Introduction

What is a corporation? Simply speaking, a corporation is a production organisation set up and operated by contracts. What is a family? A family is a unit held together and organised by blood or affection. It is widely believed and proven that a corporation is more efficient than a household or an individual in industrial production. That is why large factories inevitably replaced family workshops following the first Industrial Revolution. However, does this hold true in agricultural production? Is an agricultural corporation more efficient than a traditional family farm? To date, there is no definitive conclusion.

By 2013, there were more than 570 million farms worldwide, most of which were small and family operated. Family farms manage about 75% of the world's agricultural land (Lowder *et al.,* 2016). In other words, family farms remain the dominant form of agricultural production worldwide. The broad existence of family farms must have its rationale. Initially, the vulnerability of the agricultural production process makes it difficult to both supervise and assess the labour input involved in that process. In other words, family members, connected by blood or affection and share in the core profits of agricultural production, are thought to be more trustworthy than the mere employed. Secondly, agriculture depends heavily on land when compared to other industries, and with arable land usually owned or used by independent and dispersed farm households, it is highly challenging to concentrate land to achieve a large scale of business in agriculture. This is truest in the regions whose agricultural sector mainly consists of peasant households, such as Asian or African areas. Thirdly, it is more difficult to concentrate capital in the agricultural sector. That is, the nature of some agriculture's productive process is incompatible with the requirements of capitalist production and unattractive for capitalist penetration (Mann and Dickinson, 1978). Those theories explain the dominance of family farms in agriculture worldwide, namely, why it is difficult to develop agricultural corporations, yet fall short in providing evidence that family farmers are superior to agricultural corporations in production efficiency.

Peasant households had long been considered backward and inefficient until Schultz (1967) proposed his famous hypothesis that peasant households are poor but efficient. What has followed is years of debate on the efficiency of peasant households and a wave of empirical work designed to test his theory (e.g. Adams, 1986; Lipion, 1968; Popkin, 1980). Recently, researchers in this field are more interested in examining and comparing the production efficiency of family farms with different-sized operations and testing the hypothesis of the inverse farm size-productivity relationship, which states that small farms are more productive than larger farms (Carletto *et al.,* 2013; Charnes *et al.,* 1978; Chayanov 1991; Cornia 1985; Kagin *et al.,* 2016; Larson *et al.,* 2014; Sen, 1962; Schultz, 1980). Thus far, the issue of production efficiency of family farms has been systematically and elaborately examined. However, rare studies refer to the comparison of production efficiency between family farms and agricultural corporations. Hence, we have neither evidence nor a conclusion on which form of agricultural production holds the advantage in production efficiency.

The research question fuelling this paper is whether agricultural corporations have an advantage over family farms in terms of production efficiency. The key hypothesis put forward is that agricultural corporations are more efficient than

family farms in production efficiency. This advantage, if it in fact exists, may stem from the fact that the former is established and operated by contract, while the latter is maintained and operated by blood relations. This implies that the former is more adept in flexibly adjusting the input of production factors, thus making its production efficiency higher than the latter. More importantly, taken together with the finding from the existing literature that operation size has an extremely significant effect on production efficiency (Fujie and Senda, 2022; Perdomo *et al.,* 2022), this paper focuses on estimating and comparing production efficiency between family farms and agricultural corporations of the same operation size to verify whether agricultural corporations are superior to family farms in terms of production efficiency.

More concretely, this paper builds a quantitative framework for measuring the technical and allocative efficiency (inefficiency) of agricultural production in family farms and agricultural corporations, respectively, via estimating the stochastic production frontier functions. An economic entity's production process may exhibit technical inefficiency, allocative inefficiency, or both. Technical inefficiency is defined as the unsuccessful minimisation of input usage to produce given outputs or the unsuccessful maximisation of outputs using given inputs. Allocative inefficiency is described as the failure to combine inputs in optimal proportions to minimise the production costs, namely, failure to equate the marginal rate of technical substitution (MRTS) between any two inputs to the ratio of corresponding input prices (Atkinson and Cornwell, 1994; Farrell, 1957; Kopp and Diewert, 1982; Zhang *et al.,* 2019). Obviously, the former inefficiency is price-independent, and the latter is price-related.

This paper enriches the existing literature on agricultural production efficiency analysis by including agricultural corporations in the analytical framework. It is the first attempt to evaluate technical and allocative efficiency for both family farms and agricultural corporations. It reveals that agricultural corporations do not retain an advantage over traditional family farms in production efficiency, but the disparity between the two forms of agricultural production diminishes as their operation size increases. These findings have rich policy implications for developing new forms of agricultural production. Exploring further methods of increasing the production efficiency of agricultural corporations should be a component of a new strategy of agricultural modernisation.

The rest of the paper is organised as follows. Section 2 describes the methodology of evaluating the technical and allocative efficiency and decomposing the TFP growth. Section 3 introduces the data adopted in this paper and groups the research objects. Section 4 reports the empirical results, while Section 5 concludes.

Methodology

Measurement of Technical Efficiency

The present paper identifies and compares the technical and allocative efficiency of family farms and agricultural corporations by estimating a stochastic production frontier model. Stochastic frontier models have been widely applied in the analyses of the efficiency of agricultural production (Aigner *et al.,* 1977; Battese and Coelli, 1992; Battese and Coelli, 1995; Meeusen and Julien 1977; Perdomo *et al.,* 2022; Zhang *et al.,* 2019).

An agricultural management entity is technically inefficient when it operates beneath its stochastic production frontier. Thus, the production technology of an agricultural corporation can be characterised by a production function of the form:

$$y = a_0 \prod_{i=1}^{n} x_i^{a_i} e^{v-u}, \tag{1}$$

where y is the agricultural output of the agricultural management entities, the x_i are the inputs to the production process, a_0 and a_i are parameters, v is a random error term that captures random variation in output due to factors outside the control, which is distributed as $N(0, \sigma_v^2)$, and u is a non-negative disturbance and reflects technical inefficiency, which is distributed as $N^+(0, \sigma_u^2)$.

The log-linear form of this production function can be written as:

$$\ln y = \ln a_0 + \sum_{i=1}^{n} a_i \ln x_i + v - u. \tag{2}$$

Obviously, $\ln y$ is bounded from above by the stochastic production frontier:

$$\ln a_0 + \sum_{i=1}^{n} a_i \ln x_i + v, \tag{3}$$

with technical efficiency relative to the frontier given by u percent.

The log-linear form of this production defined in Equation 2 is used to estimate technical efficiency. In fact, besides the production system approach, a form of stochastic cost frontier is also widely used to identify and measure technical and allocative efficiencies (Kumbhakar, 1997; Mosheim and Lovell, 2009). However, Kumbhakar and Wang (2006) point out that the estimates of a cost frontier function can be easily biased without the cost of allocative inefficiency being included explicitly. Here, we do not adopt the form of a cost system approach mainly for another reason. To make the technical efficiency comparison between family farms and agricultural corporations meaningful, we must put them at the same production or cost frontier. However, this condition cannot be satisfied in the estimation of cost frontier because family farms and agricultural corporations do not encounter the same factor markets. In other words, they face systematically different prices of production factors. This point is of great importance. Put simply, an agricultural corporation might be identified as being more technically efficient in the estimates of the cost frontier model, but such technical efficiency is due to lower prices of input factors rather than the input factors being less in quantity. Intuitively, in terms of technical efficiency, we only want to observe which production form can use less input to produce the same output or which can produce more output using the same amount of input. Therefore, the production system approach is better suited to such an objective.

Measurement of Allocative Efficiency

As stated previously, allocative inefficiency is defined as the degree of failure to combine inputs in optimal proportions to minimise the production costs: in other words, failure to equate the marginal rate of technical substitution between any two inputs to the ratio of corresponding input prices. Thus, by adding the first-order conditions for cost minimisation into the production function defined as Equation 1, we will have:

$$\frac{f_j}{f_1} = \frac{p_j}{p_1} e^{\xi_j}, \tag{4}$$

where f_j represents the first derivation of the production function for input j, p_j is the price for input j, and ξ_j is interpreted as the allocative inefficiency for the input pair (j,1). x_1 is the numeraire. The sign ξ_j shows whether input j is over- or underused relative to numeraire input 1. A positive sign means input j is underused relative to input 1, while a negative sign means input j is overused relative to input 1.

Equation 4 can also be rewritten as:

$$\frac{\partial \ln y}{\partial \ln x_j} \div \frac{\partial \ln y}{\partial \ln x_1} \equiv \frac{s_j}{s_1} = \frac{p_j \cdot x_j}{p_1 \cdot x_1} e^{\xi_j} = \frac{a_j}{a_1}, \tag{5}$$

where s_j is cost share of input j, which is defined as $s_j = p_j \cdot x_j / c$ and $c = \sum_j p_j \cdot x_j$. Taking logs for Equation 5 yields:

$$\ln(a_j/a_1) - \ln(p_j/p_1) - \ln x_j + \ln x_1 = \xi_j. \tag{6}$$

Due to the linear homogeneity in input prices, only relative inefficiency can be estimated using Equation 6. In the following analysis, we choose land as the numeraire to estimate relative allocative inefficiency.[1]

TFP Decomposition

To examine the technical and efficiency changes, this paper decomposes the TFP growth in family farms and agricultural corporations, respectively. There are various approaches used to decompose TFP, including parametric estimation of production or cost functions, non-parametric indices, exact index numbers, and non-parametric methods using linear programming (Bauer, 1990; Kalirajan *et al.,* 1996; Kumbhakar *et al.,* 2015). Following the above method of estimating technical and allocative efficiency, we use the parametric estimation of the production function to decompose the TFP. The production function has been defined as Equation 1. Meanwhile, TFP change, which measures the productivity change, can be expressed in the form of:

$$\dot{TFP} = \dot{y} - \sum_j s_j \dot{x}_j. \tag{7}$$

Differentiating Equation 1 totally and combing it with Equation 7, we will have:

$$\begin{aligned} \dot{TFP} &= TC - \frac{\partial u}{\partial t} + \sum_j \left(\frac{f_j x_j}{f} - s_j\right) \dot{x}_j = \\ &(RTS - 1) \sum_j \lambda_j \dot{x}_j + TC + TEC + \\ &+ \sum_j (\lambda_j - s_j) \dot{x}_j, \end{aligned} \tag{8}$$

where $TC = \frac{\partial \ln f(\cdot)}{\partial t}$, is the measure of technical change; $TEC = -\frac{\partial u}{\partial t}$, is the measure of technical efficiency change; and $RTS = \sum_j \frac{\partial \ln y}{\partial \ln x_j} = \sum_j \frac{\partial \ln f(\cdot)}{\partial \ln x_j} = \sum_j f_j(\cdot) x_j \equiv \sum_j \epsilon_j$, is the measure of returns to scale. ϵ_j is the input elasticity defined as the production frontier. $\lambda_j = f_j x_j / \sum_k f_k x_k = \epsilon_j / RTS$.

In this way, we can decompose *TFP* into scale components, $(RTS - 1) \sum_j \lambda_j \dot{x}_j$, technical progress, *TC*, technical efficiency change, *TEC*, and change in allocative efficiency, $\sum_j (\lambda_j - s_j) \dot{x}_j$.

Data and Grouping

Data

This paper adopts the aggregate data from the Statistical Survey on Farm Management and Economy (Statistics code: 00500201) conducted by the Ministry of Agriculture, Forestry, and Fisheries of Japan. This survey is conducted on and summarises family farmers and agricultural corporations of different sizes. Japan's Statistical Survey on Farm Management and Economy divides family farms into ten grades and agricultural corporations into four grades according to their operating land scale, as shown in Figure 1. It reports the averages of various inputs and outputs of family farms and agricultural corporations on different operating land sizes each year. Taking into account the fact that production techniques and outputs vary greatly across different agricultural product sectors, we choose single rice farming entities, the family farms and agricultural corporations in which more than 80 percent of their total agricultural sales is rice, as research objects. Our observation period spanned 2004 to 2016. Hence, this paper adopts a panel data set with 14 observations for 13 years.

To facilitate the quantitative analysis, a rich set of data on Japanese family farms and agricultural corporations is compiled. In Japan, the decreasing birth rate and ageing population are becoming problematic for its agriculture. The number of peasant households in Japan has plummeted from 1.98 million in 2005 to 0.99 million in 2021, while the average age of agricultural workers has soared to 62.3 years. In such context, a countermeasure put forward by the Japanese government has been vigorously to develop agricultural production corporations.[2] The number of agricultural corporations in Japan has more than doubled from 13.9 thousand in 2005 to 31.6 thousand in 2021 (Table 1).

[1] The estimation results will not be affected by choice of the input used as the numeraire. Thus, the choice of determining the numeraire can be arbitrary (Kumbhakar *et al*., 2015; Khataza *et al*., 2019).

[2] Agricultural corporations are defined as operating entities that engage in agriculture and are registered as legal persons in Japan. That is to say, the process of setting up, managing, and disbanding or abolishing agricultural corporations must satisfy the conditions of legal persons (enterprise counting and taxing system, etc.). Refer to Appendix 1 for the classification of Japan's agricultural corporations.

Table 1: Composition of Agricultural Management Entities in Japan, in Thousand and Percentage, 2005-2021.

Number of Agricultural Management Entities					
Year	Total	Individual	Organisation		% of Corporation
			Total	Corporation	
2005	2,009.4	1,981.3	28.1	13.9	0.69
2006	1,935.8	–	–	–	–
2007	1,867.0	–	–	–	–
2008	1,804.1	–	–	–	–
2009	1,753.2	–	–	–	–
2010	1,679.1	1,648.1	31.0	17.1	1.02
2011	1,617.6	1,586.1	31.5	–	–
2012	1,563.9	1,532.7	31.2	17.8	1.14
2013	1,514.1	1,482.4	31.7	18.2	1.20
2014	1,471.2	1,439.1	32.1	18.9	1.28
2015	1,377.3	1,344.3	33.0	22.8	1.66
2016	1,318.4	1,284.4	34.0	23.8	1.81
2017	1,258.0	1,223.1	34.9	24.8	1.97
2018	1,220.5	1,185.0	35.5	25.5	2.09
2019	1,188.8	1,152.8	36.0	26.1	2.20
2020	1,075.7	1,037.3	38.4	30.7	2.85
2021	1,030.9	991.4	39.5	31.6	3.07

Source: Data are from the database of the Ministry of Agriculture, Forestry, and Fisheries of Japan

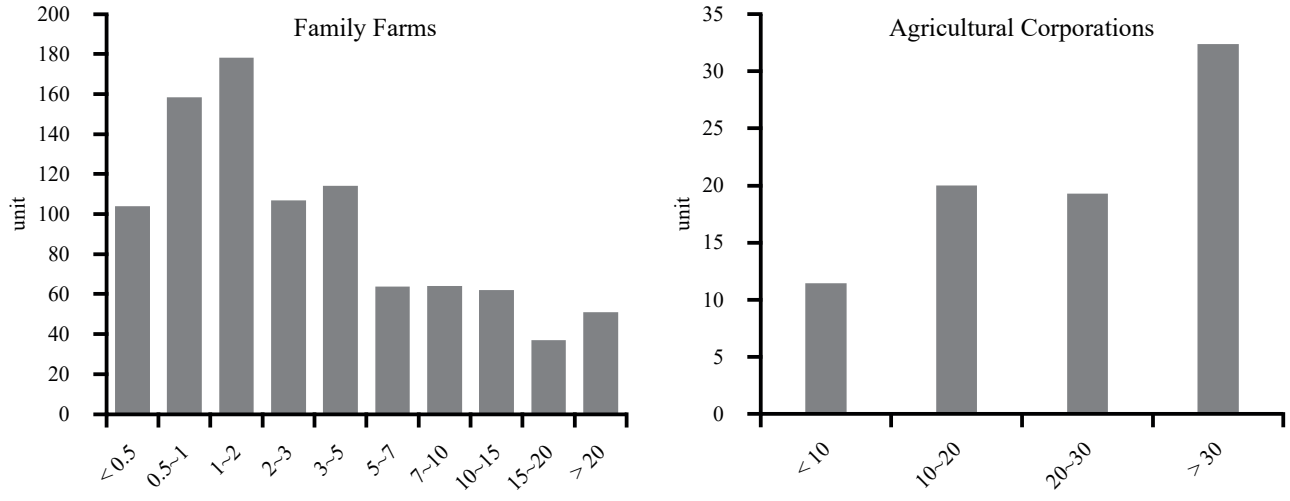

Figure 1: Distribution of Rice Family Farms and Rice Agricultural Corporations in Land Size.
Source: Japan's Statistical Survey on Farm Management and Economy

Figure 1 displays the average number of single rice farming family farms and single rice farming agricultural corporations at each level of land size from 2004 to 2016.[3] Japan's Statistical Survey on Farm Management and Economy divides family farms into ten grades and agricultural corporations into four grades according to their operating land scale, as shown in Figure 1. The operating land scale of the majority of rice family farms is under 2 hectares, while that of most rice farming agricultural corporations is above 10 hectares. As mentioned above, it is crucial to compare family farms and agricultural corporations of the same operation size on the grounds that even though we can empirically prove that agricultural corporations produce rice more (or less) efficiently than family farms, it is hard to say whether and to what extent the gulf between them is due to the difference in operation form or merely the variation in operating land scale. To address this problem, we split family farms and agricultural corporations into four groups according to their operating land scale and compare the technical and allocative efficiency between the two forms of agricultural production within each group.

[3] Single rice farming entities refer to family farms and agricultural corporations in which more than 80 percent of their total agricultural sales is rice.

Table 2: Description of Variables and Data Sources.

Variable	Unit	Description	Source
		Output	
Rice Output	kg	Annual gross rice output per household/ corporation	Statistical Survey on Farm Management and Economy (Statistics code: 00500201)
		Input	
Labour Input	hour	Labour hours input in rice production per household/corporation consisting of hours input of family members and employed workers	Statistical Survey on Farm Management and Economy (Statistics code: 00500201)
Agricultural Fixed Assets	1000 yen	Fixed assets relative to rice production owned by per household/corporation	Statistical Survey on Farm Management and Economy (Statistics code: 00500201)
Cultivated Land	hectare	Area of land sown with rice per household/ corporation consisting of owned land and rented land	Statistical Survey on Farm Management and Economy (Statistics code: 00500201)
Other Costs	1000 yen	Costs consisting of expenses in seedlings, fertiliser, agricultural chemicals, relative materials and fuel, and power	Statistical Survey on Farm Management and Economy (Statistics code: 00500201)
		Price Index	
Price Index of Fixed Assets	100	Price index of agricultural implements (2015=100)	Statistical Survey on Prices in Agriculture (Statistics code: 00500204)
Price Index of Other Costs	100	Price index of other materials for agricultural production (2015=100)	Statistical Survey on Prices in Agriculture (Statistics code: 00500204)
		Factor Price	
Labour Wage	yen/ hour	Average wage weighted by household labour input and employment labour input	Calculated from the Statistical Survey on Farm Management and Economy (Statistics code: 00500201)
Rate of Interest	%	Interest rate of borrowing	Calculated from the Statistical Survey on Farm Management and Economy (Statistics code: 00500201)
Land Rent	yen/ 10ha	Average land rent weighted by owned land and rented land	Calculated from the Statistical Survey on Farm Management and Economy (Statistics code: 00500201)
		Others	
Ratio of Employed Labour	%	Percentage of hours input of employed labour in total hours input	Calculated from the Statistical Survey on Farm Management and Economy (Statistics code: 00500201)
Ratio of Borrowed Land	%	Percentage of borrowed land area in the total cultivated land area	Calculated from the Statistical Survey on Farm Management and Economy (Statistics code: 00500201)

Source: Own composition

Table 2 describes each of the variables used in the estimation and its data sources. To estimate the stochastic production frontier model, we choose gross rice output (in kgs) as the output variable. For input variables, we select labour input (in hours), agricultural fixed assets (in thousand Japanese yen), the area of arable land (in hectares), and other costs (in thousand Japanese yen), which consists of expenses in seedlings, fertiliser, agricultural chemicals, various relative materials and fuel, and power. Note that labour input includes both family labour input and hired labour input, and land input combines owned land and rented land. Agricultural fixed assets and other costs are deflated to the prices of 2015. The relevant data on the price index are from the Statistical Survey on Prices in Agriculture (Statistics code: 00500204) published by the Ministry of Agriculture, Forestry and Fisheries of Japan. Labour wage is calculated by dividing total labour cost by labour hours. Land rent is calculated by dividing the total cost of land rent by the area of borrowed land. Agricultural capital price is calculated by dividing debt interest by total debt.[4]

Grouping

It is well-known that land size plays a crucial role in assessing and explaining the performance of family farms (Chayanov, 1991; Hall and LeVeen, 1978; Helfand and Levine, 2004; Henneberry *et al.,* 1991; Khataza *et al.,* 2019; Mottaleb and Mohanty, 2015; Weersink and Tauer, 1991;

[4] The database of Management Statistics by Farming Type does not cover the relative data for calculating the input prices for single rice farming family farms. Hence, we use the database of Agricultural Production Costs, which also belongs to the Statistical Survey on Farm Management and Economy (Statistics code: 00500201), to calculate the input prices for single rice farming family farms.

Table 3: Division of Operating Land Size.

Form	Hectare	Group
Family Farms	<0.5	1
	0.5-1	
	1-2	
	2-3	
	3-5	
	5-7	
	7-10	2
	10-15	3
	15-20	
	>20	4
Agricultural Corporations	<10	2
	10-20	3
	20-30	4
	>30	

Source: Own composition

Wolf and Sumner, 2001). To eliminate the effect of land size on assessing economic efficiency and to obtain as accurate as possible comparison results of production efficiency between family farms and agricultural corporations, we split family farms and agricultural corporations into four groups according to their operating land scale. As shown in Table 3, we classify family farms whose operating land scale is under 7 hectares as group one and classify family farms between 7 and 10 hectares and agricultural corporations under 10 hectares as group two. Note there is neither subdivision for the agricultural corporations under 10 hectares nor a group one, as the average operating land scale of agricultural corporations under 10 hectares is over 7 hectares. Thus, we classify agricultural corporations under 10 hectares separately from family farms under 7 hectares. The family farms and agricultural corporations between 10 and 20 hectares are classified as group three, and family farms and agricultural corporations above 20 as group four. In such a way, the operating scale of family farms and agricultural corporations differs little within each group. Hence, in the following analysis, we will be intent on comparing the technical and allocative efficiency of family farms and agricultural corporations within each group.

The summaries and comparison of variables between family farms and agricultural corporations within each group are reported in Table 4. Variations in the quantity of each input factor are insignificant between family farms and agricultural corporations within each group, suggesting our division is reasonable. Also prominent is that within each group the amount of labour input hours, agricultural fixed assets, cultivated land, and others expended in rice production by agricultural corporations is higher than that of family farms. But in terms of output levels, agricultural corporations do not always produce more rice than family farms. Only in group four (above 20 ha) is the average rice output of agricultural corporations greater than that of family farms. This might forebode that our hypothesis that agricultural corporations are more efficient than family farmers in agricultural production may be challenged.

It is worth mentioning the difference in factor prices paid by agricultural corporations and family farmers in each group. In group two (7-10 ha) and group three (10-20 ha), the average labour wage of family farms is higher than that of agricultural corporations. The situation in group four (above 20 ha) is the opposite. In all groups, the average interest rate (capital price) and land rent of agricultural corporations are lower than those of family farms. This implies that compared with traditional family farms, agricultural corporations tend to have more market power in the factors market and thus can obtain production factors at a lower price, especially in the capital and land rent markets.

Results

Estimates of Technical Efficiency

Initially, we estimated the production frontier aggregately for family farms and agricultural corporations. The parametric estimates for the frontier production function appear in Table 5. Model 1 shows the results with family farms and corporations estimated aggregately. For reference, we also estimate their production frontier separately and report the estimation results. Models 2 and 3 include

Table 4: Intra-group Comparison of Mean Values of Variables.

	< 7 ha	7-10 ha		10-20 ha		>20 ha	
	Family Farms	Family Farms	Corporations	Family Farms	Corporations	Family Farms	Corporations
Rice Output	12,714	42,840	34,929	76,932	68,911	137,323	173,230
Labour Input	642	1,752	1,927	2,631	3,287	4,131	6,768
Agricultural Fixed Assets	2,496	6,538	10,572	11,441	13,391	20,294	23,127
Cultivated Land	313	1,044	1,226	1,802	2,044	3,139	4,591
Other Costs	687	2,209	2,802	3,820	4,165	7,036	10,092
Labour Wage	1,417	1,489	1,183	1,538	1,260	1,512	1,686
Rate of Interest	3.87	3.61	0.45	3.48	0.80	3.42	0.74
Land Rent	16,136	17,772	11,034	16,992	12,354	16,976	13,507
Ratio of Employed Labour	6.01	8.95	18.68	13.34	26.01	23.49	36.79
Ratio of Borrowed Land	22.96	52.06	87.32	52.98	97.72	62.47	94.39

Source: Own composition

the results with family farms and corporations estimated separately. All the estimated coefficients are statistically significant in the three models except capital, whose coefficient is insignificant in Model 1 and Model 3. The estimated coefficient of ln capital is negative in Model 3. This is mainly because agricultural capital is over-invested to some extent in agricultural corporations, and thus as capital inputs increase, output first rises and then falls. That is, rice output and capital inputs show an inverted U-shaped relationship in agricultural corporations. For that reason, we add the square of the ln Capital into Model 3 and re-estimate the stochastic frontier production of agricultural corporations, shown in Model 4.

The return to scale is 0.772, 0.759, 0.902, and 1.05 in the four models, respectively. According to the results of the Wald test, the former two are significantly less than 1, but the last two are not markedly different from 1. The estimated parameter σ_u is much greater than that of σ_v, suggesting deviations from the production frontier are primarily due to technical inefficiency. The null hypothesis that there does not exist an inefficiency component is rejected, thus justifying the use of the stochastic frontier approach.

In Model 1, the estimated coefficients of ln Labour, ln Capital, and ln Land are 0.154, 0.021, and 0.300, respectively. In Model 2, the estimated coefficients of ln Labour, ln Capital, and ln Land are 0.127, 0.110, and 0.215, respectively. In Model 3, they are 0.120, -0.037, 0.502, and 0.317, respectively. After including the square of the lnCapital, the coefficient of lnCapital becomes 0.133, while minor deviations are observed in the other coefficients. These results echo those of the existing literature. Ajibefun *et al.* (2002) estimated the translog stochastic frontier production function of Japanese rice farms for 1984-1994. According to their estimation results, the coefficients of lnLabour, lnCapital, and lnLand are 0.191, 0.210, and 0.163, respectively. Considering their chosen paper period, the estimates appear to reflect the situation of family farms. Hence, in comparing their results with ours from Model 2, we can see that the coefficient of lnCapital is smaller than theirs by almost twice, and variations in the other coefficients are minimal.

Table 6 summarises the technical efficiency estimated from the stochastic frontier models. The first and the second columns are estimated from Model 1. The third column comes from Model 2, and the fourth column is derived from Model. 4. For comparison, the efficiency scores from the Data Envelopment Method (DEA) are included in the last columns.[5]

Table 5: Parametric Estimates of the Stochastic Frontier Production Function.

	Aggregated	Family Farms	Corporations	
	Model 1	**Model 2**	**Model 3**	**Model 4**
ln Labour	0.154***	0.127*	0.120*	0.120*
	(0.045)	(0.070)	(0.064)	(0.065)
ln Capital	0.021	0.110***	−0.037	0.133
	(0.022)	(0.037)	(0.032)	(0.560)
ln Land	0.300***	0.215**	0.502***	0.483***
	(0.079)	(0.104)	(0.130)	(0.147)
ln Others	0.297***	0.308***	0.317***	0.320***
	(0.065)	(0.078)	(0.123)	(0.125)
ln Capital * ln Capital	–	–	–	−0.009
	–	–	–	(0.029)
sigma u	0.434	0.493	0.176	0.183
sigma v	0.043	0.040	0.047	0.047
Observations	182	130	52	52

Note: Models 1-4 use Modified-LSDV time-varying fixed-effect estimators. Standard errors are reported in parentheses. Significant levels are * 0.10, ** 0.05, *** 0.01
Source: Own calculations

Table 6: Technical Efficiency Estimations.

Group	Aggregated		Separated		DEA	
	Family Farms	**Corporations**	**Family Farms**	**Corporations**	**Family Farms**	**Corporations**
<7 ha	0.446	–	0.433	–	0.890	–
7-10 ha	0.707	0.504	0.712	0.640	0.899	0.657
10-20 ha	0.847	0.689	0.855	0.818	0.930	0.758
>20 ha	0.988	0.922	1.000	0.982	0.958	0.900
Average	0.607	0.759	0.602	0.856	0.906	0.804

Source: Own calculations

[5] The method of DEA refers to Appendix 2. For related literature, refer to Liu *et al.* (2015), Mao and Koo (1997), and Sarac *et al.* (2022).

Let us view the estimated technical efficiency from the stochastic frontier production function. There are some interesting findings. First, technical efficiency is higher in family farms than in agricultural corporations, whether estimated aggregately or separately. For example, according to the estimation results from aggregated estimation, the average technical efficiency of family farms is 0.446 in farm sizes below 7 hectares (group one). It means that family farms in this group, on average, produce around half of their maximum potential output due to technical inefficiency. In farm sizes between 7-10 hectares (group two), technical efficiency is 0.707 in family farms and 0.504 in agricultural corporations. In group three, between 10-20 hectares in size, it is 0.847 in family farms and 0.689 in agricultural corporations. In farm sizes above 20 hectares (group four), technical efficiency is 0.988 in family farms and 0.922 in agricultural corporations. Second, the disparity in technical efficiency between the two production forms diminishes as farm size increases. According to the results from the aggregated estimation, the gap in technical efficiency between the two is 0.20 in group two (7-10 ha), 0.16 in group three (10-20 ha), and 0.07 in group four (above 20 ha). As for the results from the separated estimation, the gap in technical efficiency between the two is 0.07, 0.04, and 0.02 in the three groups, respectively, displaying the same law. Lastly, technical efficiency rises with farm size increases, whether in family farms or agricultural corporations. In other words, the larger the entity's land scale is, the larger its technical efficiency is. This rule applies to family farms and agricultural corporations.

The findings from the DEA method are comparable, except that the relative level of technical efficiency in agricultural corporations is much lower. For example, based on parametric estimation of the frontier production function, the technical efficiency of agricultural corporations between 7-10 hectares is larger than that of family farms below 7 hectares. However, based on the DEA method, the technical efficiencies of agricultural corporations sized between 7-10 hectares and 10-20 hectares are smaller than that of family farms below 7 hectares.

In short, our results confirm that family farms are more technically efficient than agricultural corporations at the same level of operating land scale. However, Fujie and Senda (2022) adopt DEA to estimate and compare the production efficiency between family farms and agricultural corporations in the Japanese rice sector. They argue there is no significant difference in efficiency between corporate farms and family farms on average. But they also point out that the efficiency of family management significantly exceeds the efficiency of corporate management at the medium- and large-scale operations, confirming the superiority of family farms in the medium- and large-scale groups. However, they use agricultural gross income rather than rice output as the output variable in estimates, which involves the effect of the rice sale price. The same problem arises in the paper of Dong (2022), whose results show that agricultural corporations exhibit higher production efficiency than family farms in Japanese agriculture. Taking the effect of the rice sale price difference between the two production forms into account, we have reason to believe that our estimates and results are more reliable and reflect the reality of agriculture in Japan.

Moreover, importantly, our estimations show that rice production's technical efficiency rises as farm size increases. This finding seems incongruous with the hypothesis of the inverse farm size-productivity relationship, which depicts that small farms are more productive than larger farms and has been widely discussed and verified in existing literature (Carletto *et al.,* 2013; Charnes *et al.,* 1978; Chayanov, 1991; Cornia, 1985; Kagin *et al.,* 2016; Larson *et al.,* 2014; Schultz, 1967; Sen, 1962). However, there are two notable differences between those studies and our findings. Firstly, productivity is not equal to production efficiency. Many measurements have been used to represent productivity, and the most often used is the net value or net weight of output per unit of cultivated land (Carletto *et al.,* 2013; Kagin *et al.,* 2016; Muyanga and Jayne, 2019). Secondly, those studies supporting the inverse farm size-productivity relationship mainly examine smallholder farms between zero and 10 hectares or so. However, division is crucial in verifying such a relationship. Muyanga and Jayne (2019) examined farms in Kenya with a broader range of farm sizes (≤ 5ha, 5-20ha, >20ha) and detected a U-shaped relationship between farm size and farm productivity. Specifically, they found that the inverse relationship hypothesis holds true on farms between zero and 3 hectares, the relationship between farm size and productivity is relatively flat between 3 and 5 hectares, and a strong positive relationship between farm size and productivity emerges within the 5 to 7 hectares range of farm sizes. Hence, we can see how much the distribution and grouping of samples affect the verifying results of the hypothesis.

How about the relationship between land productivity and farm size for the two forms in our paper? Figure 2 shows the relationship between land productivity and farm size. Unlike the hypothesis of the inverse farm size-productivity relationship, the relationship between land productivity and farm size is more like an inverse U-shape in both family farms and agricultural corporations. That is to say, land productivity first increases and then decreases as farm size expands and similarly, land productivity is greater in family farms than in agricultural corporations at a similar farm size.

Estimates of Allocative Efficiency

In the following analysis, we mainly use the estimated results of the stochastic frontier production function from Model 1 to examine the allocative efficiency of family farms and agricultural corporations. There is no relative data for calculating the prices of seedlings, fertiliser, and others for agricultural corporations in the statistics of such a period. Hence, we only consider the three inputs of labour, capital, and land when estimating allocative efficiency in this section. The prices of the three input factors are summarised in Table 4. Note that for both family farms and agricultural corporations, the wage of family labour and the rent of self-owned land are included when calculating the input prices.

An estimation of allocative inefficiency is reported in Table 7.[6] With land as the numeraire, we find that labour and capital are overused in both family farms and agricultural corporations. This phenomenon is mainly due to a serious shortage of arable land in Japan and thus the high relative price of arable land to labour and capital, shown in Table 4. Both family farms and agricultural corporations try to fully utilise farmland by devoting more resources to other factors in production.

In terms of labour, the absolute value of family farms is less than that of agricultural corporations, suggesting the allocative inefficiency of labour is larger in agricultural corporations. Namely, the overuse of labour is more serious in agricultural corporations. As farm size increases, allocative inefficiency improves in family farms. This is because as operating land size expands, the ratio of employed labour used in family farms increases, shown in Table 4. Apparently, a family farm with a high ratio of employed labour can adjust labour input more elastically, such as responding to labour wage change, than a family farm full of family labour. Nevertheless, such a rule is not applicable to agricultural corporations. Even though the ratio of employed labour in agricultural corporations also rises as their operating land size expands, the allocative inefficiency of labour in agricultural corporations rises rather than decreases as operating land size expands. This difference between the two production types is probably due to the fact that employment contracts in family farms are usually for a short period, while employment contracts in agricultural corporations are usually for a long period, which results in family farms performing better in adjusting labour input when responding to the change in labour wage than agricultural corporations do on average. It is important to note that the allocative inefficiency is highest in family farms below 7 hectares, suggesting the biggest challenge for an agricultural management entity full of family labour is adjusting relative labour input in response to changes in labour wage. Our findings further support the existing conclusion on the advantages of family farms in using labour. For example, Kostov *et al.* (2019) verified the superiority of family farms relative to agricultural corporations in the organisational efficiency of family labour by examining family and corporate farms of EU Member States. However, our results document that the superiority of family farms might be more embodied in the distribution of family labour and employed labour according to labour wage. The situation is reversed when it comes to capital. The allocative inefficiency of capital is larger in family farms, as the overuse of capital is much more severe in family farms. Over-investment in the Japanese rice sector has been elaborated on and proven in existing literature (e.g. Hara and Hitoshi, 2008). The disparity of allocative inefficiency of capital between family farms and agricultural corporations is mainly due to the distinguished ability to acquire loans from financial institutions and invest in agricultural capital. Exactly, agricultural corporations are more likely to obtain low-interest loans than family farms. The lending interest rate they obtain is much lower than that for family farms, as shown in Table 6. It implies that agricultural corporations can obtain more credit when increased agricultural capital is required. They need not invest in precautionary agricultural capital since they can obtain credit more easily than family farms. Therefore, agricultural corporations have a higher ability to adjust agricultural capital in response to changes in capital price.

TFP Decomposition

By applying the data into Equation 8, we can decompose and compare TFP for family farms and agricultural corporations, respectively.[7] Changes in inputs and RTS of family farms and agricultural corporations are reported in Table 8. Labour input and agricultural capital used per management entity declined in family farms from 2004 to 2016. The situation in agricultural corporations is basically the same, except that labour input increases in agricultural corporations below 20 hectares. Regarding land, the area of arable land used increases in family farms below 20 hectares but declines in those above 20 hectares. The situation in agricultural corporations is the opposite. The area of arable land used declines in agricultural corporations below 20 hectares but increases in those above 20 hectares. These findings confirm our conclusion on allocative efficiency above. Namely, labour and capital are both overused relative to land in family farms and agricultural corporations. Thus, both family farms and agricultural corporations tend to reduce these two factors' input and expand the area of arable land.

Table 7: Allocative Inefficiency Estimations.

Group	ξ_l		ξ_k	
	Family Farms	**Corporations**	**Family Farms**	**Corporations**
<7 ha	-1.419	-	-3.039	-
7-10 ha	-1.090	-1.302	-2.488	-0.940
10-20 ha	-1.025	-1.307	-2.507	-1.370
>20 ha	-0.899	-1.384	-2.487	-0.844
Average	-1.250	-1.344	-2.822	-0.999

Source: Own calculations

[6] The values of the coefficients of lnLabour, lnCapital, and lnLand used to estimate the allocative inefficiency are 0.15, 0.12, and 0.30. The value of the coefficient of lnCapital adopts the mean value of the coefficient of lnCapital from Model 2 and that from Model 4, considering the estimated value is far smaller in Model 1.

[7] Considering the data of separate prices of fertiliser for the two entity types are unavailable, we also only consider the three inputs of labour, capital, and land in decomposing TFP, similar in the estimates of allocative efficiency. The re-estimation of the translog stochastic frontier production function for TFP decomposition is reported in Appendix 3.

Table 8 shows that RTS is greater than 1 (increasing return to scale) except in agricultural corporations above 20 hectares. This finding seems contradictory to what we found in Table 5. Such inconsistency occurs mainly because we only consider labour, capital, and land in decomposing TFP and exclude other factors. However, we can see that RTS decreases as farm size increases. It declines from 1.22 in farm size below 7 hectares (group 1) to 1.04 for those above 20 hectares (group 4) in family farms. In agricultural corporations, it declines from 1.11 to 0.91. These data are in line with our expectations.

Based on Table 8, we decompose TFP for family farms and agricultural corporations, respectively. The results of the decomposition of TFP are summarised in Table 9. The scale component is -0.16 in family farms and -0.22 in agricultural corporations on average. Recall Table 8, the negative scale component is mainly driven by the declining input. Technical change is, on average, -0.28 in family farms and 0.26 in agricultural corporations, suggesting technical progress is faster in agricultural corporations than in family farms. In addition, as farm size increases, technical progress becomes faster accordingly, regardless of the type.

Technical efficiency change, TEC, is 0.33 in family farms and 0.75 in agricultural corporations. It reveals that even though family farms show a larger technical efficiency than agricultural corporations, as concluded in Section 4, the improvement in technical efficiency is more rapid in the latter. As to allocative efficiency, the previous analysis reveals that family farms show superiority in the allocative efficiency of labour, and agricultural corporations show superiority in the allocative efficiency of agricultural capital. However, the change in allocative efficiency is positive in family farms but negative in agricultural corporations. This phenomenon might be due to average prices of most input factors being higher in family farms than in agricultural corporations, as shown in Table 4.

Consequently, family farms are sensitive to changes in input prices and are incentivised to improve their allocative efficiency. Furthermore, the allocative efficiency component is the largest contributor to each TFP of family farms and agricultural corporations. Hence, this drives TFP positively in family farms but negatively in agricultural corporations. Besides, it is important to note that TFP increases in agricultural corporations as farm size increases, which also suggests that the larger the agricultural corporation is, the better it is. Importantly, our findings from TFP decomposition deepen our understanding of the relationship between TFP change and operation size by involving agricultural corporations. Much existing literature confirms that the driving factors behind the TFP growth of family farms of different operation sizes are different (Rahmatullah and Kuroda, 2005; Fan and Chan, 2005; Hu, 1995; Kuroda, 1989). Our findings reveal this rule is also applicable to agricultural corporations.

Table 8: Changes in Inputs and RTS.

%, unit

		Family Farms	Corporations
< 7 ha	% Growth of Labour	-0.52	–
	% Growth of Capital	-3.11	–
	% Growth of Land	0.84	–
	RTS	1.22	–
7-10 ha	% Growth of Labour	-1.27	0.87
	% Growth of Capital	-2.21	-1.49
	% Growth of Land	1.77	-0.43
	RTS	1.10	1.11
10-20 ha	% Growth of Labour	-0.27	0.15
	% Growth of Capital	-2.54	-3.21
	% Growth of Land	1.31	-1.06
	RTS	1.08	1.01
>20 ha	% Growth of Labour	-0.18	-1.17
	% Growth of Capital	-3.74	-3.95
	% Growth of Land	-0.09	0.41
	RTS	1.04	0.91
Average	% Growth of Labour	-0.51	-0.33
	% Growth of Capital	-2.97	-3.15
	% Growth of Land	0.93	-0.16
	RTS	1.16	0.98

Source: Own calculations

Table 9: Decomposition of TFP.

%

		Family Farms	Corporations
< 7 ha	TFP	1.19	-
	Scale	-0.13	-
	TC	-0.55	-
	TEC	0.23	-
	Allocative	1.73	-
7-10 ha	TFP	0.04	-15.98
	Scale	-0.23	-1.80
	TC	-0.08	0.01
	TEC	-0.01	-0.34
	Allocative	0.37	-13.85
10-20 ha	TFP	-0.37	-8.63
	Scale	-0.21	-0.39
	TC	0.13	0.20
	TEC	0.69	0.81
	Allocative	-0.97	-9.24
>20 ha	TFP	0.60	-5.05
	Scale	-0.18	0.66
	TC	0.34	0.42
	TEC	0.51	1.27
	Allocative	-0.07	-7.40
Average	TFP	0.69	-8.68
	Scale	-0.16	-0.22
	TC	-0.28	0.26
	TEC	0.33	0.75
	Allocative	0.85	-9.47

Source: Own calculations

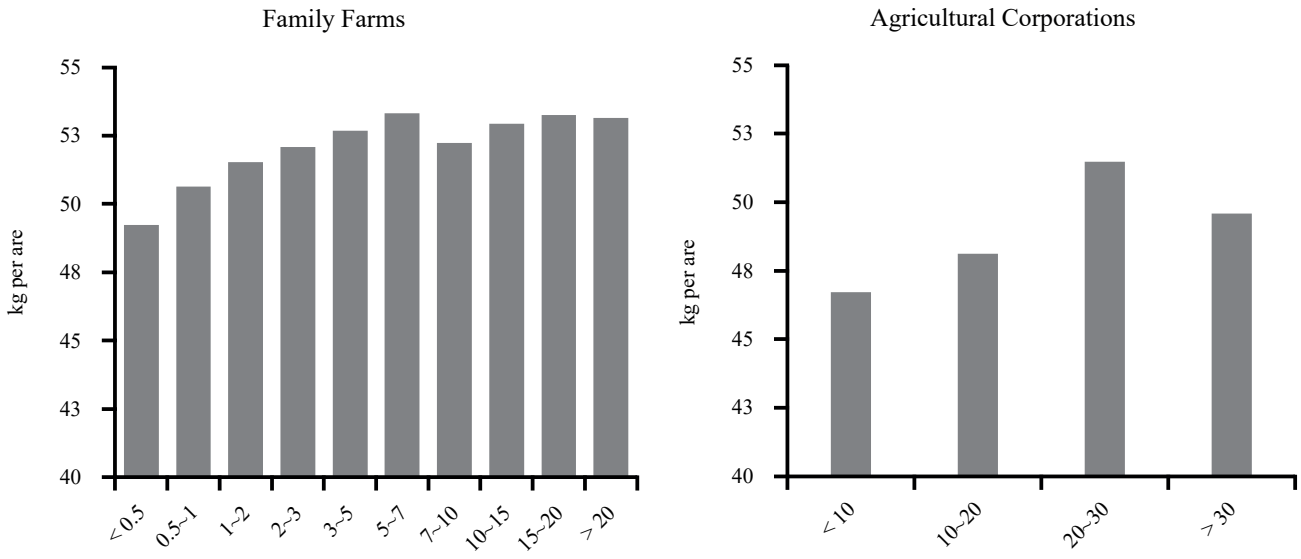

Figure 2: Farm Size and Land Productivity.
Source: Own calculations

Conclusions

This paper attempts to answer the question of whether an agricultural corporation is more efficient than a traditional family farm, a subject which is both important and forward-looking. As an extension and development of the existing theory on the production efficiency of family farms, this paper provides crucial evidence for assessing and comparing production efficiency between traditional family farms and agricultural corporations systematically.

Our analysis found that family farms have a significant advantage over agricultural corporations in technical efficiency at each level of operation scale. It reveals that the family farm can utilise input factors to maximise output more efficiently than agricultural corporations in rice production. Moreover, the results show that larger operation scale is accompanied by higher technical efficiency in both family farms and agricultural corporations. The disparity in technical efficiency between the two forms diminishes as farm size increases. This implies that once farm size becomes large enough and exceeds a certain degree, the advantage of family farms may vanish. Those findings differ from the existing studies (Dong, 2022; Fujie and Senda, 2022), which argue that there is no significant difference in technical efficiency between the two production forms or that agricultural corporations are superior to traditional family farms in technical efficiency. Unlike recent studies, we chose rice output weight as the output variable to eliminate the effect of rice sale prices on the measurement of technical efficiency and adopted the stochastic production frontier method, which is more flexible and adaptable in form than the DEA method. Hence, our estimation results are more reasonable and credible.

The findings in allocative efficiency are more complicated. In fact, allocative efficiency varies from family farms to agricultural corporations, as well as across different input factors and across land scales. Overall, family farms exhibit superiority in the allocative efficiency of labour, and agricultural corporations show superiority in the allocative efficiency of agricultural capital. Both labour and capital relative to land are overused in family farms and agricultural corporations. This can be put down to the severe shortage of agricultural land in Japan, which makes the relative of land much higher than the prices of other inputs.

Based on the analysis of technical and allocative efficiency, we decomposed TFP to examine the changes in TFP and in each of its components. Overall, family farms have positive TFP change, which is mainly contributed by a positive and large allocative component. In contrast, agricultural corporations experience negative TFP change which is largely driven by its negative and large allocative component. Separately, technical progress and efficiency improvement are faster in agricultural corporations than in family farms. By contrast, family farms are superior to agricultural corporations in scale effect and allocative efficiency improvement.

Reviewing what we have learned thus far, we can draw a conclusion and discuss the reasons behind it. Firstly, overall, family farms are more technically efficient than agricultural corporations at the same level of operation land scale. There are two possible explanations as to why this is the case. For one, we have seen that prices of most input factors, mainly referring to labour and land, are higher for family farms than for agricultural corporations. That makes family farms use input factors more carefully and sparingly. For another, the ratio of employed labour and the ratio of borrowed land are both lower in family farms relative to agricultural corporations of the same operation size. This makes agricultural production more stable in family farms and makes it easier to plan various inputs during the production process and, thus, more possible to maximise agricultural output. More than that, we also see that as farm size increases, the disparity in technical efficiency between the two forms narrows. A probable reason is that as farm size increases, the ratios

of employed labour and borrowed land rise in family farms, therefore, diminishing their advantage in technical efficiency.

Secondly, the superiority of family farms and agricultural corporations in allocative efficiency varies across input factors. Simply speaking, family farms are better at utilising labour, while agricultural corporations are better at utilising capital. A likely explanation is that employment in family farms is more flexible than in agricultural corporations and that agricultural corporations have better access to credit. Lastly, family farms perform better in improving allocative efficiency, and agricultural corporations are better equipped to improve technical efficiency and progress. This reveals traditional family farms are more sensitive to changes in the prices of input than agricultural corporations, and the latter has a stronger ability for technical innovation. Hence, our hypothesis that agricultural corporations are more efficient than family farms in production efficiency is mostly rejected in this paper.

The work provides some interesting insight and suggestions for developing agricultural production entities. First, we have proven that, on average, family farms are superior to agricultural corporations in technical efficiency. That being so, the replacement of family farms with agricultural corporations will generate net welfare loss unless we can reverse this problem. Accordingly, future studies must figure out which factors result in lower technical efficiency in agricultural corporations. Secondly, irrespective of the analysis of technical and allocative efficiency or the analysis of decomposing TFP, the golden rule shown is that the larger an agricultural corporation is, the better it is. In other words, the superiority of agricultural corporations is primarily embodied when their scales are large enough. Hence, the key is to develop agricultural corporations of large land scale.

Finally, we would like to address the limitations of this paper. Although we have proven that traditional family farms exceed agricultural corporations in production efficiency, we must respect the rapid rise of agricultural corporations in Japan. Our findings do not attempt to provide reasons for this movement in Japanese agriculture. Rather, the theme requires more in-depth examination via future studies. A reasonable argument is that agricultural corporations have a remarkable advantage over traditional family farms in maintaining higher rice sale prices and lower input factors prices. However, this supposition needs further systematic verification and discussion, which we plan to undertake as a follow-up.

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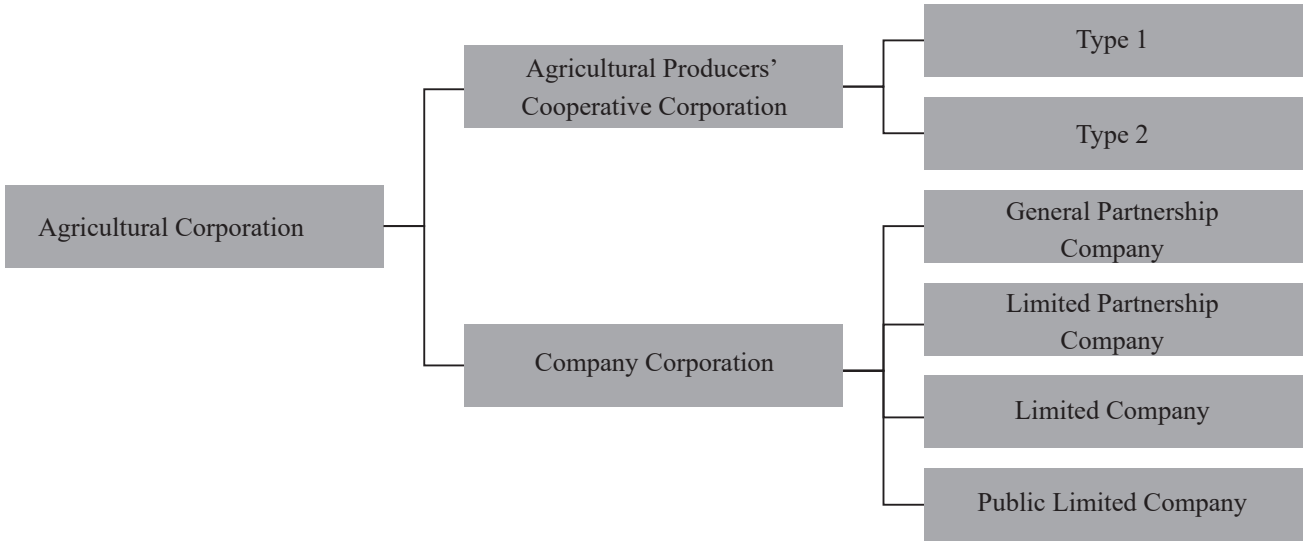
Appendix

Appendix 1: Types of Agricultural Corporations in Japan



Source: Own composition

Appendix 2: DEA Method

Data Envelopment Analysis (DEA) was initially proposed by Charnes (1978) measuring to assess the operational efficiency of the decision-making unit (DMU) in public programs in order to improve the planning and control of these activities. This method is widely used in measuring operational efficiency and technical change in many fields, including agriculture. In this method, the efficiency of any DMU is obtained as the maximum ratio of weighted outputs to weighted inputs subject to the condition that the similar ratios for each DMU be no more than unity. In more precise form, it can be expressed as:

$$\max_{v,u} \theta = \frac{u_1 y_{1i} + u_2 y_{2i} + \cdots + u_m y_{mi}}{v_1 x_{1i} + v_2 x_{2i} + \cdots + v_n x_{ni}} \tag{B-1}$$

subject to

$$\frac{u_1 y_{1j} + u_2 y_{2j} + \cdots + u_m y_{mj}}{v_1 x_{1j} + v_2 x_{2j} + \cdots + v_n x_{nj}} \leq 1 \ (j = 1, \cdots, t) \tag{B-2}$$

$$u_p \geq 0 \ (p = 1, \cdots, m) \tag{B-3}$$

$$v_q \geq 0 \ (q = 1, \cdots, n) \tag{B-4}$$

where y_{qi} and x_{qi} are the known outputs and inputs of the *i*th DMU, p denotes the category of outputs, and q denotes the category of inputs. u_p and v_q are the variable weights of each output and input, which are called virtual multipliers and are to be determined by the solution to this problem. θ_i is the measured efficiency for the *i*th DMU. The output-oriented DEA model is used with the variable returns to scale (VRS). The output variable is gross rice output (in kgs), and the input variables are labour input in agricultural production activity (in hours), the area of cultivated land (in hectares), and agricultural fixed assets (in 10 thousand Japanese yen). The agricultural fixed assets are deflated to 2015 prices.

Appendix 3: Estimates of Parameters of the Translog Stochastic Frontier Production Functions

	Coefficient
ln Labour	2.969
	(19.114)
ln Capital	−4.604
	(18.261)
ln Land	−3.886**
	(1.701)
ln Labour * ln Labour	−3.891***
	(0.641)
ln Capital * ln Capital	−0.585***
	(0.144)
ln Land * ln Land	−2.673***
	(0.677)
ln Labour * ln Capital	0.406**
	(0.206)
ln Labour * ln Land	2.888***
	(0.650)
ln Capital * ln Land	0.186
	(0.236)
Year	−0.035
	(0.026)
Year * Year	0.000
	(0.000)
Year * ln Labour	0.001
	(0.009)
Year * ln Capital	0.003
	(0.009)
Year * ln Land	0.000
	(0.000)
sigma u	0.265
sigma v	0.038
lambda	6.933

Note. Model uses random-effects time-varying inefficiency effects model estimators. Standard errors are reported in parentheses. Significant levels are * 0.10, ** 0.05, and *** 0.01.
Source: Own calculations