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Proceedings of the International Conference on Research in Business, Management and Finance
Vol. 1, Issue. 1, 2024, pp. 17-24
DOI: https://doi.org/10.33422/icrbmf.v1i1.519
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ISSN: 3030-1106 online

The Impact of Digital Technologies on Farm Operational Activities: A Case Study Analysis Between Germany and Finland

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Abstract

Digitalization is a fundamental component of the European Commission's (EC) initiative to modernize agriculture, its associated activities, and rural areas within the European Union (EU). Advancements in digitalization, including robots, sensors, drones, global positioning systems (GPS), and online platforms, have created new activities, products, and services, significantly impacting farm operational activities. This study explores the potential future implications of digitalization in livestock farming in Baden-Württemberg (Germany) and North Savonia (Finland). The focus will be on examining how digital technologies transform livestock farming practices. The findings highlight the potential benefits of digitalization in improving animal welfare, efficiency, and sustainability, and addressing challenges in the livestock sector. Quantitative instruments were used to assess how implemented digital technologies impact farm activities. In addition, a structured questionnaire with specific questions was created and distributed online to farmers involved in livestock farming. Farmers in both countries reported that the use of digital technologies improved their working conditions, safety and health standards, decision-making processes, and product quality. Farmers in Finland and Germany had different opinions regarding the influence of digitalization on several aspects of farming. Finnish farmers noted a significant impact of digitalization on improving cooperation with other chain actors and access to new markets and financial resources, contrary to farmers in Germany. Digital adoption on farms has a significant impact beyond the farm since it influences decision-making and sustainability outcomes as the food chain becomes more vertically integrated.

Keywords: digitalization, decision-making, efficiency, livestock, on-farm activities

1. Introduction

Digitalization is defined as one of the main cornerstones of the EC for transforming agriculture and rural territories in the EU. It is referred to as the use of digital technologies

and data as well as interconnection that results in new or changes to existing activities (OECD, 2019). According to Nambisan et al., (2017), digitalization describes socio-technical processes and their impacts on human activities resulting from using interconnected digital technologies. Khanna, (2021) defines the digital transformation of agriculture as an enabler for increasing production efficiency, reducing overapplication of inputs and waste, and improving farm profitability.

Several studies have shed light on major technological developments and associated innovations. One of the most important is the introduction of milking robots or automatic milking systems (Straete et al., 2017). Rowe et al., (2019) argue that precision livestock farming (PLF) can help farmers improve their productivity and profitability due to more precise control over the production process. It involves the application of technologies that allow continuous real-time monitoring of individual animals (Berckmans, 2017), increase on-farm production efficiency, and bring forward automation of operational tasks.

The solutions offered by digital farming technologies for the preservation of natural resources and the welfare of animals have increased the demand for technological advancements in agriculture. In Europe, the highest user rates of digital technology are currently seen in Germany, France, and the Netherlands (Maloku, 2020), focusing mostly on farm management information systems (FMIS), barn cameras, and sensors. The primary goal of animal husbandry in the country is the production of cattle, pigs, and poultry (Germany Trade and Invest [GTAI], 2023). for measuring the behavior of individual animals (Gabriel & Gandorfer, 2023).

Germany was listed as the third-largest producer of agricultural machinery worldwide in 2022, behind China and the United States. Data collection, processing, and intelligent automation technologies are key areas of focus in developing new machinery, and advancements are being made in sensor technologies, robotics, automation, artificial intelligence, and big data. The production of cattle, pigs, and poultry is the main focus of livestock in the nation (Germany Trade and Invest [GTAI], 2023).

In Finland, the agricultural sector is characterized by the use of modern technology, high environmental and animal welfare standards and practices, and significant profitability challenges (European Commission [EC], 2023). Over the last decade, the total production volume has not changed, despite nearly 48% of the dairy farms ceasing operations (Ruokatieto, 2021). The increased productivity has mostly been attributed to advances in production and farm management technologies (Niskanen, 2020). The implementation of digital technologies has gained particular interest as it enables improved animal monitoring. Digital livestock technologies (DLT) can offer real-time monitoring and management systems, improving animal health and welfare, increasing product yields, and giving farmers better control over livestock management (Berckmans, 2014). However, the development and adoption of technologies for sustainable farming differ across OECD countries.

There is little evidence available regarding the potential impacts of DLT on farm management practices and its benefits for the farming community. This study examines how digitalization is transforming farm activities and optimizing livestock operations to improve efficiency and sustainability.

2. Methods

The research has been conducted in the North Savo region of Finland and Baden-Württemberg, Germany. To investigate the impact of digital technology on farm operations, a structured questionnaire was created and distributed online to farmers involved in livestock

production in the respective regions. The questionnaire structure, the digital technologies used in livestock farming, and the questions were designed and modified to suit the Finnish and German contexts. The survey was conducted over three months, from November 2023 to January 2024. A total of 128 questionnaires were considered valuable. The types of livestock farms considered for the survey were: dairy and beef cows, pigs, sheep, goats, laying hens, and broilers. The main types of livestock farms consisted mainly of dairy and beef cows (83%) and farms with mixed animals (17%).

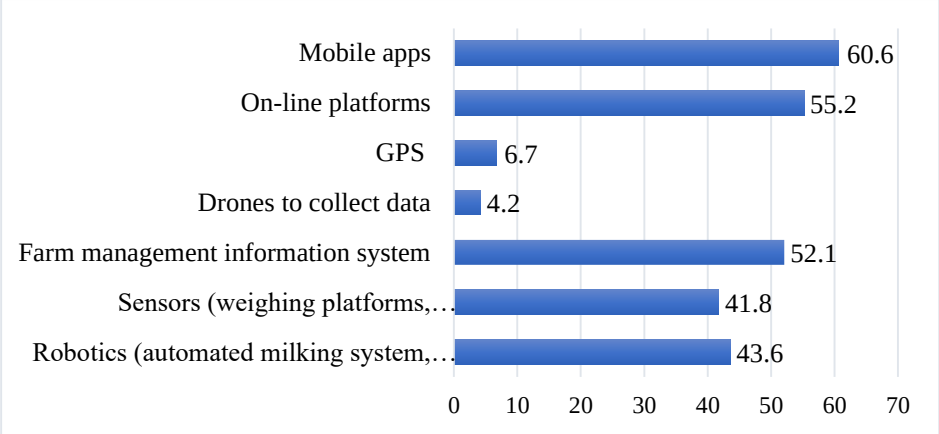
In a specific section of the questionnaire, farmers were asked to respond to statements using a 5-point Likert-type scale (1 = strongly disapprove, 2 = disapprove, 3 = neutral, 4 = approve, and 5 = strongly approve). The statements were related to the influence of digital technologies on various aspects of farm operations. Data analysis, including descriptive statistics, was completed using the SPSS program.

3. Results and discussion

3.1. Implementation level of digital technologies in livestock farms

Policymakers and stakeholders in the food industry are increasingly focused on the impact of digital technologies in livestock farming. The level of implementation of these technologies directly affects overall productivity and sustainability on farms.

Figure 1: Level of digital technology adoption in %



Source: (Authors contribution)

The findings indicated that the most commonly used technologies included FMIS, automatic milking systems, sensors, barn cameras, online platforms, and mobile apps (Fig. 1).

3.2. Similarities and differences of digitalization impact in Finnish and German farms

3.2.1. Access to public services and market

Digitalization is crucial for improving the accessibility of public services and the management of livestock. Due to the implementation of digital technologies, the livestock industry can more easily adopt cutting-edge technologies and enhance the efficiency of farm operations. Besides, digital platforms that provide e-commerce services are a popular way for small and medium-scale farmers to participate in formal economies. Farmers now have direct access to market information and can trade their produce. According to the data in Table 1, farmers in Germany and Finland had differing views on the influence of digitalization on

farm aspects. Finnish farmers reported that using digital tools improved their access to public services (85%), financing (91%), and markets (82%).

Table 1: The indicated impact of digital technologies on access to public services and the market

Statement of Farmers in Finland					
Farm aspects	**Strongly disapprove**	**Disapprove**	**Neutral**	**Approve**	**Strongly approve**
Improvement of access to financial resources	2.9	5.9	41.2	41.2	8.8
Improvement of access to new markets	0	17.6	35.3	41.2	5.9
Increase in product diversification	5.9	20.6	55.9	11.8	5.9
Improvement of access to public services	0	15.2	39.4	39.4	6.1
Statement of Farmers in Germany					
Improvement of access to financial resources	14	29	39.8	10.8	6.5
Improvement of access to new markets	18.3	30.1	40.9	10.8	0
Increase in product diversification	17.2	29	43	9.7	1.1
Improvement of access to public services	14	31.2	31.2	19.4	4.3

Source: (Authors contribution)

The findings align with other studies, indicating that the application of smart applications enables farmers to access enhanced markets, thereby increasing sales (Vaintrub et al., 2021). In contrast, German farmers reported an average impact of digitalization on farm operations, as detailed in Table 1.

3.2.2. Product Quality

Animal welfare is recognized as a crucial aspect of the broader concept of food quality, and it has become increasingly apparent that there is a strong connection between animal welfare and the safety of the food derived from these animals (Boyle and O'Discroll, 2011). Participating farmers in the survey identified milking robots, calving sensors, and health parameters (temperature measuring and activity) as the main digital techniques that are already being used. Implementing these technologies provides farmers with more information on each animal's state of health and activities, allowing them to better understand the factors that influence the welfare of animals and, as a result, improve production quality. The results in Table 2 show that digital technologies have a major impact on improving the quality assurance system, starting at the farm level.

Table 2: The indicated impact of digital technologies on product quality and safety standards

Statement of Farmers in Finland					
Farm aspects	**Strongly disapprove**	**Disapprove**	**Neutral**	**Approve**	**Strongly approve**
Increase in product quality	5.9	14.7	29.4	35.3	14.7
Improvement of safety and health standards	0	11.8	35.3	35.3	17.6
Statement of Farmers in Germany					
Increase in product quality	3.2	15.1	28	48.4	5.4
Improvement of safety and health standards	5.4	9.7	34.4	45.2	5.4

Source: (Authors contribution)

The feedback received from farmers in both countries confirms that the use of PLF technologies has improved the health and well-being of animals. As a consequence, safety

concerns have become less prevalent. Related to these aspects, there was a similarity in the frequency of responses among farmers in both countries. Specifically, 88% of Finnish farmers and 85% of German farmers reported these positive outcomes.

3.2.3. Decision-making process and operational cost

Digital technologies can improve agricultural decision-making processes and forecast future outcomes by improving food chain traceability, precisely identifying animals and products, and gathering and analyzing data.

The information presented in Table 3 shows that farmers noticed a significant impact of digitalization on improving working conditions and the decision-making process. Approximately 65% of farmers in both countries stated that digital technologies have a moderate effect on reducing the number of employees. This evidence further supports the assertion that PLF technologies can assist farmers in detecting problems and making management decisions (Buller et al., 2020).

Table 3: The indicated impact of digital technologies on the decision-making process and operational costs

Statement of Farmers in Finland					
Farm aspects	**Strongly disapprove**	**Disapprove**	**Neutral**	**Approve**	**Strongly approve**
Reduction in the number of employees	8.8	26.5	35.3	26.5	2.9
Improved working conditions	2.9	14.7	8.8	44.1	29.4
Decrease in farm/business operational costs	0	3	60.6	30.3	6.1
Improvement in support of farm decision-making process	0	11.8	38.2	38.2	11.8
Statement of Farmers in Germany					
Reduction in the number of employees	8.6	25.8	23.7	30.1	11.8
Improved working conditions	4.3	16.1	16.1	38.7	24.7
Decrease on-farm/business operational costs	14	34.4	38.7	11.8	1.1
Improvement in support of farm decision-making process	8.6	12.9	25.8	41.9	10.8

Source: (Authors contribution)

According to the findings, farmers' responses to operating expenditures differed across the two countries. Finnish farmers underlined a strong emphasis on the importance of digital tools in lowering operational expenses (97%), whereas German farmers have not seen a similar impact, with roughly 50% entirely disagreeing. However, it is crucial to note that the farms included in the study are small to medium-sized, thus the influence on operational cost reduction may be less evident.

3.2.4. Cooperation and communication

The emergence of specific digital tools and technologies has been recognized as a potential solution to overcome critical problems such as high transaction costs, information asymmetries, access to customers, public services, and cooperation with actors in the agri-food chain (Duric', 2020). The opportunities derive from the increased availability of data across the entire livestock production chain, along with the combination of various data sources to develop knowledge. Rectifying the information imbalance between suppliers, livestock farmers, processors, distributors, and consumers, while improving transparency along the chain, will enhance confidence in the sector and give consumers access to a wider

variety of products. In addition, by changing the perspectives of farmers, producers, and consumers, the use of digital technologies in the livestock farming industry has the potential to revolutionize this sector (Thakur et al., 2024).

According to the data in Table 4, 74% of Finnish farmers reported that the implemented technology had a major impact on improving interaction with other parties in the supply chain. These findings contrast with the results of German farmers, who reported only 32% having a significant influence.

Table 4: The indicated impact of digital technologies on cooperation with stakeholders and customers

Statement of Farmers in Finland					
Farm aspects	**Strongly disapprove**	**Disapprove**	**Neutral**	**Approve**	**Strongly approve**
Improvement of cooperation with public institutions	0	20.6	35.3	41.2	2.9
Improvement of cooperation with other actors in the chain	0	14.7	11.8	67.6	5.9
Improvement of access to customers	0	11.8	47.1	26.5	14.7
Statement of Farmers in Germany					
Improvement of cooperation with public institutions	16.1	24.7	26.9	29	3.2
Improvement of cooperation with other actors in the chain	9.7	24.7	26.9	29	3.2
Improvement of access to customers	9.7	21.5	47.3	19.4	2.2

Source: (Authors contribution)

The results indicated that digitalization has a moderate effect on enhancing cooperation with public institutions for Finnish farms (44%), while its impact on German farms can be considered low (32%). There is a divergence of opinions between farmers in the two countries regarding the improvements brought about by the adoption of digital technology in accessing new and existing customers. Specifically, 41% of Finnish farmers observed an enhancement in this aspect, while only 21% of German farms acknowledged a similar impact.

4. Conclusion

The use of digital agricultural technologies provides valuable opportunities for livestock farmers. These technologies enable farmers to easily access a wide range of data across the whole production chain and combine different sources of information to generate useful insights. As the livestock industry continues to progress, farmers can improve operational efficiency, ensure food safety, and enhance the quality of their products while promoting sustainable practices.

This study found that Finnish and German farmers experienced similar benefits from adopting digital technologies. These technologies had a significant positive impact on ensuring a better animal living environment, reducing stress, improving health conditions, better animal welfare, and consequently higher-quality products. The outcomes observed in Finland and Germany reinforce the potential of these innovations to transform livestock farming. Similarly, Herlin et al., (2021) conclude that by gathering critical data on animal physiology, behavior, and environmental conditions, these technologies improve animal welfare and maximize the overall efficiency and sustainability of agricultural operations. Furthermore, automated technology such as feeding systems and health monitoring tools,

along with sensors, has not only increased productivity and improved the efficiency of resources, but also has significantly improved working conditions and enhanced the decision-making process for farmers. Recent and previous studies, (Dayoub et al., 2024; Davenport et al., 2020) have shown that smart farming applications improve livestock marketing and distribution across the chain by providing real-time information and facilitating enhanced decision-making processes.

The results revealed significant disparities in how Finnish and German farmers use digital technologies. These dissimilarities are primarily related to access to finances, public services, and new markets. However, the impact of digitalization is not solely dictated by technological advancements, and not all farms could gain equally from the adoption of a new technology. For instance, according to Beck et al. (2024), farms in confined regions (less favored areas) may function inefficiently in geographically constrained areas. Furthermore, EU member states address these problems in varying ways through national or regional policies, resulting in disparities in how digital tools are integrated not just in private but also in governmental organizations. Furthermore, more research is required to properly understand the varying effects of these factors in each country.

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