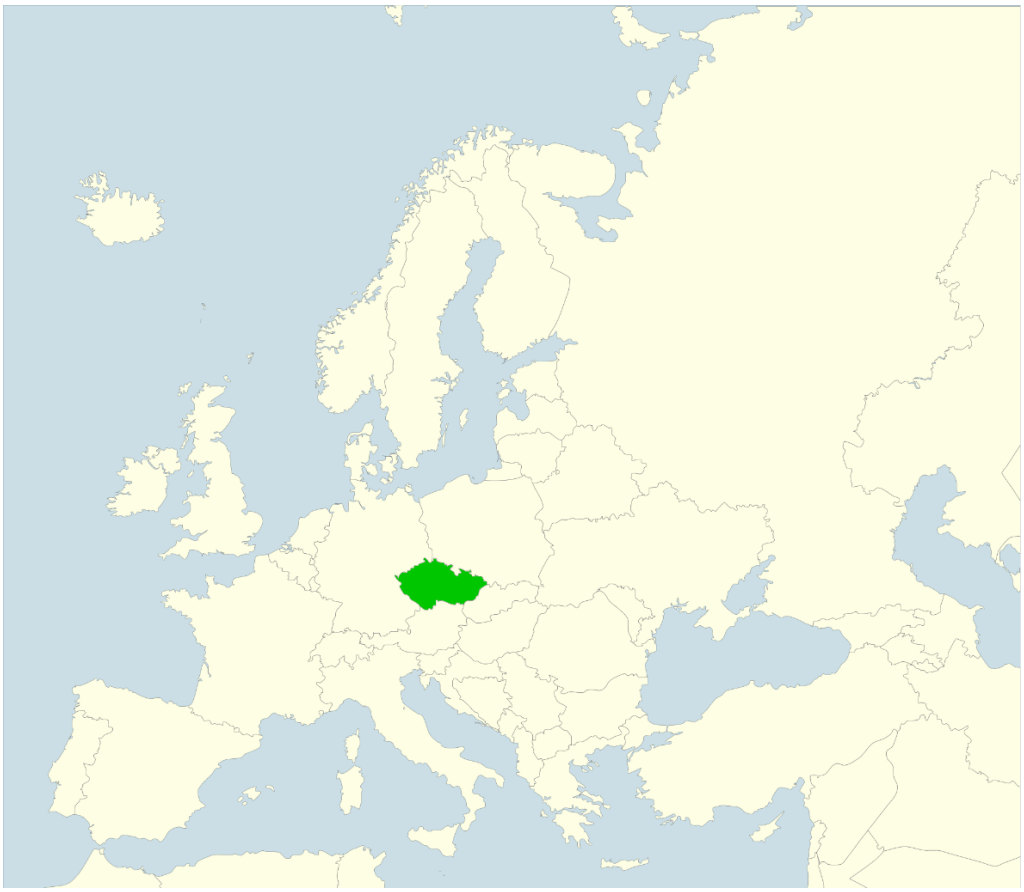
European Countryside | volume 15 | No. 1 | p. 99-123 | DOI: 10.2478/euco-2023-0006

CONTESTING THE ROLE OF DIGITISATION AND ICT IN THE BUSINESS MODEL OF AGRICULTURAL HOLDINGS AND FARMERS: MICRO-STUDY OF THE INNER RURAL PERIPHERY REGION IN THE CZECH REPUBLIC

Martin Pělucha, Jana Nováková, Alexander Shemetev, Jana Kouřilová[1]





[1] Prof. Ing. Martin Pělucha, Ph.D., corresponding author, ORCID: 0000-0003-2024-5964, e-mail: martin.pelucha@vse.cz, Ing. Jana Nováková, ORCID: 0000-0002-7992-6548, e-mail: ja.novakova18@gmail.com, Dr.phil. Alexander Shemetev, ORCID: 0000- 0003-0563-3491, e-mail: aleksandr.shemetev@vse.cz, RNDr. Jana Kouřilová, Ph.D., ORCID: 0000-0002-4219-3141, e-mail: jana.kourilova@vse.cz, Department of Regional Studies, Faculty of Economics, Prague University of Economics and Business, Czechia

Received 17 July 2022, Revised 7 November 2022, Accepted 22 November 2022

Abstract: The challenges of new rural technological possibilities in the 21st century resonate with agriculture. These represent, in particularly the improving availability of ICT infrastructure and the digitisation of socioeconomic processes. This paper focuses on exploring issues related to the potential change in the business behaviour of agricultural holdings and farmers following digitization and the use of ICT. The empirical research was carried out in the territory of the Local Action Group (LAS) Železnohorský region, which is a typical inner rural periphery with a strong agricultural base. The paper presents both the results of an exploratory survey and also develops a specific empirical model according to the improved Cobb-Douglas production function with specifics of the agrarian sector (i.e., including the role of agricultural subsidies and also the application of advanced ICT). The results in the selected rural micro-region showed that the process of digitisation has been very marginal in the models of functioning of the relevant agricultural entities. The current prevailing "techno-optimist approach" in EU strategic planning needs to be overcome by more intensive and comprehensive support for the digitisation process in rural peripheral areas. Particularly, this involves a necessary combination of support for investment in ICT infrastructure and new technologies with more intensive support for digital literacy and knowledge empowerment, which will enable more intensive exploitation of the potential and possibilities of digital technologies and virtual environments.

Keywords: digitisation, agriculture, inner rural periphery, rural development

Highlights:

- Potential and limits of digitisation in agricultural management in a rural microregion.
- The functioning and behaviour of farmers following digitisation and the use of ICT.
- The results showed a relatively low level of use of digital technologies.
- Digital technologies do not greatly affect employment and supplier-customer relations.
- The challenge is strengthening farmers' proactive approach to digital technologies.

1. Introduction

Agriculture is currently facing major challenges, such as climate change, lack of natural resources, or the growth of the world population, to which the volume of world food production will also have to adapt (Saiz-Rubio & Rovira-Más, 2019; Vats, Biel & Clercq, 2018). However, the agricultural sector will have to respond further to these extra-local factors (Heley and Jones, 2012; Warlow and Kasabov, 2014), as well as to the necessity of forming more resilient rural areas (Scott, 2013; Shucksmith and Talbot, 2015) in the period of intensifying digitisation processes throughout the sector, and more intensive use of Information and Communications Technologies (ICT). These technologies have the potential for better sustainability and efficiency in agricultural management (Rotz et al., 2019). By making appropriate use of the possibilities of these trends, agriculture can positively influence the economic, environmental, and social cohesion of the rural area (Hrustek, 2020).

Albeit with some delay, the digital age is already fully reflected in the normal functioning of rural areas (Pelucha and Kasabov, 2020). However, there are still limits to the development of digitisation, which relate to the availability of ICT infrastructure, as well as the current level of digital literacy (i.e., digital skills and digital inclusion). For this reason, much attention is paid to this issue at the level of policy-making, and it is not only financial support from the EU Rural Policy but also other sectoral approaches related to the support of digitisation in business and the labour market. In this context, the general question arises regarding how these possibilities and limits of the digital age are reflected in the normal functioning of agricultural enterprises.

This paper focuses on exploring issues related to the potential change in business behaviour of agricultural holdings and farmers following digitisation and the use of ICT. Specifically, this paper presents the results of the exploratory empirical survey in the territory of the Czech inner rural periphery, which corresponds to the Local Action Group (LAG) Železnohorský Region, which has a strong agricultural and rural background. The territory of this rural microregion can be considered sufficiently representative and suitable for empirical verification because it includes both remote inner rural peripheries and smaller market towns, which form the basis of functional links in the settlement structure.

The aim of the paper is to verify the following hypothesis: Agricultural enterprises in the territory of the LAG Železnohorský Region have changed their business model of operation as a result of digitisation and the use of ICT. The verification of this hypothesis relies not only on the results of a basic descriptive analysis of an empirical survey in a selected rural micro-region but also on the elaboration of a specific empirical model according to the improved Cobb-Douglas production function (Biddle, 2021; Cobb & Douglas, 1928). In the empirical part, the authors have extended this function precisely to the specifics of the functioning of the agricultural sector, i.e., in addition to incorporating the role of agricultural subsidies, the innovative component (i.e., the application of advanced ICT). The main research gap follows the general and long-term assumption regarding the "techno-optimist approach" (i.e., technology produces good, rather than bad, results), that prevails in EU strategic planning (see Alam et al., 2018, p. 60), but, at the same time, there are significant differences in the capabilities and possibilities of rural actors to fully use the potential of the digital age (Pelucha and Kasabov, 2020).

The paper is structured as follows: The first section concerns the theoretical basis of concepts and approaches in the process of digitisation of agriculture. The second section focuses on the methodology, while partial attention is paid to the brief characteristics of the selected microregion for empirical verification, the description of the questionnaire survey, and also the way to define a representative sample of respondents (agricultural enterprises). The third section describes the results in detail, distinguishing between the situation of legal entities (i.e., larger agricultural enterprises) and natural persons (i.e., smaller farmers). The results are presented in four topics, i.e., technologies in use, refinancing of new technologies and future investments, human resources, and supplier-customer relationships. The last section of the paper is focused on the synthesis of findings, their discussion, and concluding remarks.

2. The theoretical basis of the agriculture digitisation process

What exactly is digital agriculture? Several concepts have emerged in agriculture that express various forms of digitisation in agricultural production systems, but also more generally in food systems. These include *precision agriculture*, *smart farming, decision agriculture, digital agriculture, agriculture 4.0,* or *agriculture numérique* (Klerkx, Jakku & Labarthe, 2019).

Currently, when the Fourth Industrial Revolution (Industry 4.0) is taking place, in the field of agriculture, we are talking about agriculture 4.0, which follows from precision (accurate) agriculture (Bolfe et al., 2020). Precision agriculture relates to digital technologies that are used to monitor and optimise agricultural production processes, creating a conceptual basis for smart and digital agriculture (Bolfe, et al., 2020). In smart agriculture, the emphasis is on information and data technologies, i.e., on access to data and its application, so that the collected information is used smartly. Digital agriculture integrates both precision and smart agriculture and focuses on creating value from collected data (Agrocares, 2019). It is actually about having the right data at the right time and making better decisions thanks to those data (Brini, 2018).

Saiz-Rubio and Rovira-Más (2019) do not distinguish between the terms agriculture 4.0, smart farming, and digital farming. They understand it as a combination of telematics (i.e., a combination of telecommunications and informatics) and data management, with the concept of precision agriculture. Those authors mention agriculture 5.0, from the perspective of the concept as following the principles of precision agriculture, while using devices that include unmanned operations and autonomous decision support systems. Hence, they assume the use of robotics and some forms of artificial intelligence (AI). In

this paper, digital agriculture is understood as technologies that are connected, and thanks to them the transfer of data can be further used.

Changing trends not only in agriculture are leading to a new era in which digital technologies surpass human capabilities, even for tasks that were previously impossible to automate (Hrustek, 2020). Physical control of the condition of fields and crops is not effective, and farmers' decision-making based on experience is no longer enough today – this approach is not sustainable in the future (Saiz-Rubio and Rovira-Más, 2019).

Digital agriculture uses technologies such as cyber-physical systems, the Internet of Things (IoT), artificial intelligence (AI) and machine vision, big data, cloud computing, and robotics (Hrustek, 2020). In the era of digital agriculture, machines are equipped with various kinds of sensors to measure data that need to be analysed. Machine learning and behaviour algorithms are created based on the results of the analysis of those data, and it is estimated that the IoT has the potential to increase agricultural productivity by up to 70% by 2050 (Saiz-Rubio & Rovira-Más, 2019).

Another dimension of the process of digitisation of agriculture is the level of digital literacy. ICT skills, internet use, and motivations are the fundamental conditions for digital innovation in rural areas (Räisänen and Tuovinen, 2020; Kourilova 2019). Saiz-Rubio and Rovira-Más (2019), and several other authors, draw attention to the increasing age of American and European farmers, and their reluctance to accept new technologies and modern tools. According to Voronin et al. (2020), the younger generation is important in relation to technology, because the ability to work and innovate very often gradually disappears with age. According to Bowen and Morris (2019), the development of digital and marketing skills are key drivers for further entrepreneurial activity among agrifood businesses. The main mechanism for knowledge exchange in farming communities that leads to learning and innovation is through informal networks between farmers. Another source of knowledge and innovation is the *Smart **A**gricultural **K**nowledge and **I**nnovation **S**ystem* (AKIS), which aims to integrate farmers, researchers, advisors, nature conservation experts, policymakers, and other interested parties for the easier exchange of knowledge and experience with new technologies. According to Ingram and May (2020), the promotion of joint learning and collaboration in the introduction of new technologies should be an important element of future development.

Walter et al. (2017) reflected on the liability that must exist for mismanagement or mistakes leading to economic and environmental consequences. Bolfe et al. (2020), similarly to Saiz-Rubio and Rovira-Más (2019), draw attention to the financial availability of digital technologies for small businesses, and also to the lack of internet connection in rural areas. Larger farms adopt digital technologies much more easily, simply because they have higher efficiency and returns due to larger farm units, and they are often also more supported by the vendors themselves (Brini, 2018).

Information and Communications Technologies (ICT) are key enablers for supply chain management, due to their ability to support information sharing and reduce information processing time. According to Fröhlich and Steinbiß (2020), in an increasingly competitive environment, suppliers are considered to be an important source of information, and in the future, they will not be just "another link" in the supply chain, but they will support innovation and digitisation. According to Ievoli et al. (2019), the main impact of new technologies concerns the reshaping of supplier-customer relationships and the creation of entrepreneurial activities. Thanks to ICT, the dimension of spatial proximity can be overcome and new markets and new outlets can be created.

According to the OECD (2020), the Covid-19 pandemic also presents an opportunity to accelerate the transformation of the food and agriculture sector, which would lead to greater resilience to other challenges (such as climate change). The impact of the pandemic was manifested mainly in the change in the customer structure, as there was a dramatic reduction in demand for restaurants, hotels, and hospitality. At the same time, however, the demand for supermarkets increased. According to the OECD (2020), businesses in the food chain are already adapting to changes in demand, by making more intensive use of online platforms (during the crisis associated with the Covid-19 pandemic, there was a significant increase in e-commerce), or by delivering goods directly to households. It is therefore evident that at

the level of individual concepts and theoretical approaches, the importance of digitisation in agricultural management has been clearly identified in recent years, with the fact that many authors anticipate a more significant development of a number of activities in agricultural management, as a result of the digitalisation process.

It follows from the above that there are many topics that could be addressed in this context. This paper focuses on four areas that influence each other in agricultural management, namely, the technologies used, financing of new technologies and future investments, human resources, and supplier-customer relationships. The field of new technologies is essential because new technologies are the basis for the digital transformation of not only the agricultural sector but also other sectors (ENRD, 2018). But digital technologies alone are not enough for digital transformation. As a result of the Covid-19 pandemic, there has generally been an acceleration of digitisation and greater use of innovation (Bai, Quayson and Sarkis, 2021). Vaishar and Šťastná (2019) highlighted, in this context, that it is not the coverage or availability of digital technology, but the lower skill level and conservatism of the rural population. Therefore, it is mainly human resources that, according to Trendov, Varas & Zeng (2019), determine the success of the ICT application and the use of digitisation. In this context, it is essential for companies to not only have workers with specific knowledge and skills in the field of newly available technologies but also to continue investing in their further education. Digitisation also transforms the relationships between suppliers and customers, and thus offers new alternatives to conventional customer-supplier relationships – for example, in the form of new markets (OECD, 2020). Therefore, the micro-study in this paper focuses on these key issues.

3. Methodology

3.1 Selected microregion and empirical survey

The territory of the Local Action Group (LAG) Železnohorský Region is located in the central part of the Czech Republic in its inner periphery, specifically in the Pardubice Region (NUTS III), and also it is located at the borders with the Central Bohemian Region and the Vysočina Region (see Figure 1). The relief is formed by the flat highlands of the Iron Mountains. It covers exclusively the rural areas of the inner periphery of the state in the territory of the districts of the regional capital Pardubice, and the medium-sized town of Chrudim. The territory of this LAG is internally very coherent, which is due to the fact that all sub-unions of municipalities are adjacent to each other, and thanks to the clearly identifiable territory and rural landscape. The territory of this LAG occupied 73 municipalities with an area of 510 km² and approximately 45,000 inhabitants (LAG Železnohorský Region, 2019). The LAG has a total of 67 members, including entities from the public, private, and non-profit sectors. The territory of the LAG is very agriculturally used due to the suitable relief of the landscape. Agricultural entrepreneurs focus mainly on crop production, including growing vegetables. Livestock production has a smaller scale and is focused on the production of milk, pork, beef, and chicken fattening (LAG Železnohorský Region, 2019).

Empirical research in this micro-study was divided into the areas of technology use and financing, human resources, and supplier-customer relationships. Questions in the field of technology were focused on the use of technologies that are characteristic of digital agriculture, planning of further investments, and possible financial resources for these investments, but also on the influence of human resources and other barriers to the acquisition of new technologies. In the area of human resources, the research focused on training related to the acquisition of new technologies, the importance of IT skills when recruiting new employees, and the companies' intentions for the future. The section concerning supplier-customer relationships focused on changes with the introduction of new technologies, including the connection to the Covid-19 pandemic.



Fig 1. Czech NUTS 3 regions and selection of the rural territory of the LAG Železnohorský region. Source: Ministry of Agriculture (2022), author's own modification of the map, plus additions

The basis was a survey questionnaire intended for farmers in the territory of the selected LAG, while two questionnaires were created – one for legal entities (hereinafter, LEs), and the other for natural persons (hereinafter, NPs). All three types of questions were used in the questionnaire: closed, semi-open, and open. The questionnaire was distributed online in April 2021, and each respondent was also contacted by phone to explain the purpose and significance of this empirical investigation.

In order to define **a representative sample of agricultural entities in the selected microregion**, it was necessary to request the Czech Statistical Office (hereinafter, CSO) for data on the number of agricultural entities in the territory of LAG Železnohorský Region, both legal entities (LEs) and natural persons (NPs) belonging to the group A01 – Plant and animal production, hunting and related activities according to the CZ-NACE code. According to the given criteria, a total of 809 subjects were found of which 73 subjects were not included in further research, due to the nature of their activity (e.g., hunting societies or associations). Thus, the first selection of subjects showed that a total of 736 subjects, i.e., 76 legal entities and 660 natural persons (NPs). The initial number of legal entities was considered for designing the sample of the empirical survey. In the case of natural persons, it was necessary to use an alternative approach to identify suitable respondents (see below).

In the next step, it was necessary to identify all 76 **legal entities** in the form of a public company, a limited liability company (Ltd.), a joint-stock company, and a co-operative. To identify the companies, information from the CSO was used, from which data on the name, registered office, and identification number were requested, and, at the same time, more detailed identification of the subjects was requested using the three-digit CZ-NACE code. Information from the CSO was requested by the authors with validity as of December 2020, and data regarding size and turnover were requested from the Albertina database as of March 2021.

Based on the gained information, further selection could take place: firstly, companies for which it was not possible to obtain current data later than 2018, and companies that were in liquidation or bankruptcy as of March 2021, were excluded from the research. Fifty (50) companies remained, from which those that were not actually engaged in agriculture, and companies that existed without employees and acted as intermediaries for larger joint-stock companies, were further eliminated. In particular, local knowledge, telephone communication, information on company websites, or information from financial statements from the Czech AREE (Administrative Register of Economic Entities) helped to identify these entities. After this step, only 13 legal entities remained available, to which three more were added, whose headquarters are located outside the territory of the LAG, but which actually operate on its territory.

Therefore, there were a total of 16 legal entities relevant to the questionnaire survey. A total of 14 legal entities participated in the questionnaire survey, of which 7 are joint-stock companies, 3 are limited liability companies, 3 are cooperatives, and 1 is a public company. In 64%, mixed farming prevails (i.e., animal and crop production) and in 36% only plant production prevails.

In the case of **natural persons**, it had to be considered that the CSO database includes inactive subjects or entrepreneurs who are only marginally involved in agriculture. Therefore, it was necessary to select respondents for the empirical survey in an alternative way. Thus, the authors focused on individuals who actively participated in the Czech Rural Development Programme in the period 2017 to 2019 (data are publicly available). In addition, a search was conducted for other NPs involved in agriculture that were not active members of the LAG or were not supported by the EU rural policy (in particular through LPIS – Land Parcel Identification System, and the Farmer Portal – Farmer's Register on the eagri.cz website). The empirical survey in the form of a questionnaire was conducted in April 2021. For most NPs, the same procedure as for legal entities was used – first, the respondents were contacted by phone, and only then were they sent the questionnaire. Out of the 19 NP respondents, 10 persons from the MAS and 5 from the group of others (without subsidies) completed the questionnaire, for a total of 15 NP respondents. The distribution of respondents by type of production was even, i.e., 1/3 mixed, 1/3 crop, and 1/3 animal production.

3.2 Theoretical profit maximization model for the agricultural company with subsidizing and IT- technologies components

The theoretical model of the output for agricultural companies in rural areas

Let a farming entity produces agricultural output based on labour (L) and capital (K) input in addition to component A and sells it with some price (p). The following Cobb-Douglas production function (Biddle, 2021; Cobb & Douglas, 1928) can describe the agricultural output (Y):

$$Y = p * A * K^{a} * L^{\beta} \tag{1}$$

So that $\beta = 1 - \alpha$ (2)

In addition to this, public authorities help their farmers by subsidizing part of their costs (especially in the EU by the CAP – Common Agricultural Policy) so that the government can reduce the partial cost of capital (Ω) and partial cost of labour (μ).

Suppose a farming enterprise maximizes its profit (π) while bearing the cost of capital (r) and paying salaries to its employees (w) bearing the ICT costs for labour (ICT_L) and capital (ICT_K) by solving the following problem:

$$\pi = \mathrm{Re}venue - Costs = p * A * K^{a} * L^{\beta} - (1-\Omega) * r * K * ICT_K - (1-\mu) * w * L * ICT_L \tag{3}$$

So that: $\Omega \in [0;1]; \ \mu \in [0;1]$ (with possible partial except for planned economies where subsidies can have negative values (government takes money) to lower the motivation to do economic activities in some "unplanned" spheres of production; this is not the case of the Czech Republic).

Thus, the profit maximization problem is:

$$\max_{L,K} (p * A * K^{a} * L^{\beta} - (1-\Omega) * r * K * ICT_K - (1-\mu) * w * L * ICT_L) \tag{4}$$

Therefore, the first-order conditions rely on:

$$\left\| \begin{array}{l} \frac{\partial \pi}{\partial K} = \alpha * p * A * K^{\alpha-1} * L^{\beta} - (1-\Omega) * r * ICT_K \\ \frac{\partial \pi}{\partial L} = \beta * p * A * K^{\alpha} * L^{\beta-1} - (1-\mu) * w * ICT_L \end{array} \right. \tag{5}$$

A necessary addition is estimating the positive marginal productivity of capital (MPK) and marginal productivity of labour (MPL) with fixed marginal costs of labour (MC_L) and the marginal cost of capital (MC_C):

$$\begin{cases} MPL = \beta * p * A * K^{\alpha} * L^{\beta-1} \\ MPK = \alpha * p * A * K^{\alpha-1} * L^{\beta} \\ MC_L = (1-\mu) * w * ICT_L \Rightarrow W^* \\ MC_K = (1-\Omega) * r * ICT_K \Rightarrow R^* \end{cases} \quad (6)$$

Profit maximization is only possible when:

$$\begin{cases} \alpha * p * A * K^{\alpha-1} * L^{\beta} - (1-\Omega) * r * ICT_K = 0 \Rightarrow \alpha * p * A * K^{\alpha-1} * L^{\beta} = (1-\Omega) * r * ICT_K = R^* \\ \beta * p * A * K^{\alpha} * L^{\beta-1} - (1-\mu) * w * ICT_L = 0 \Rightarrow \beta * p * A * K^{\alpha} * L^{\beta-1} = (1-\mu) * w * ICT_L = W^* \end{cases} \quad (7)$$

The log-linearising of this function simplifies solutions of power functions like (7):

$$\begin{pmatrix} \alpha-1 & \beta \\ \alpha & \beta-1 \end{pmatrix} * \begin{pmatrix} \ln(K) \\ \ln(L) \end{pmatrix} = \begin{pmatrix} (\alpha-1) * \log(K) + \beta * \log(L) \\ \alpha * \log(K) + (\beta-1) * \log(L) \end{pmatrix} = \begin{pmatrix} \log(\frac{R^*}{\alpha p A}) \\ \log(\frac{W^*}{\beta p A}) \end{pmatrix} \quad (8)$$

Or, simplifying this equation and optimizing it with (2):

$$\begin{pmatrix} \alpha-1 & 1-\alpha \\ \alpha & \alpha \end{pmatrix} * \begin{pmatrix} \ln(K) \\ \ln(L) \end{pmatrix} = \begin{pmatrix} (\alpha-1) * \log(K) + (1-\alpha) * \log(L) \\ \alpha * \log(K) + \alpha * \log(L) \end{pmatrix} = \begin{pmatrix} \log(\frac{(1-\Omega) * r * ICT_K}{\alpha p A}) \\ \log(\frac{(1-\mu) * w * ICT_L}{(1-\alpha) p A}) \end{pmatrix} \quad (9)$$

This simple question provides an optimal choice of input for receiving the maximum output holding control of governmental subsidizing of farmers and information technologies cost transferring to the output results.

Hence, the following options for ICT costs are possible:

1) $ICT_K = 1 \cap ICT_L = 1$ – digital technologies do not influence the costs of the production process and, thus, the ICT components can be outside of equation (9) because they are equal to one;
2) $ICT_K > 1 \cap ICT_L > 1$ – digital technologies increase the cost of labour and capital decreasing the overall profit-maximizing output;
3) $ICT_K < 1 \cap ICT_L < 1$ – digital technologies reduce the cost of labour and capital increasing the overall profit-maximizing output;
4) $ICT_K < 1 \cap ICT_L > 1$ – digital technologies reduce the cost of capital while increasing the cost of labour;
5) $ICT_K > 1 \cap ICT_L < 1$ digital technologies reduce the cost of labour while increasing the cost of capital;
6) $ICT_K > 1 \cap ICT_L = 1$ digital technologies increase the cost of capital without influencing labour;
7) $ICT_K < 1 \cap ICT_L = 1$ digital technologies decrease the cost of capital without influencing labour;
8) $ICT_K = 1 \cap ICT_L > 1$ digital technologies increase the cost of labour without influencing capital;
9) $ICT_K = 1 \cap ICT_L < 1$ digital technologies decrease the cost of labour without influencing capital;

The situations when an ICT component is above zero can demand additional governmental subsidies (S) (Ω (when $ICT_K > 1$) and/or μ (when $ICT_L > 1$)) in quantities sufficient to normalize the equation ICT*S so that:

$$\begin{cases}(1-\Omega)*ICT_K < 1\\(1-\mu)*ICT_L < 1\end{cases} \qquad (10)$$

Equation (10) shows the potential positive influence of public subsidies on the acquisition of digital technologies with the assistance of proper public support.

Thus, the expected overall progress of the output function with the development of ICT for developed regions should be like in figure 2.

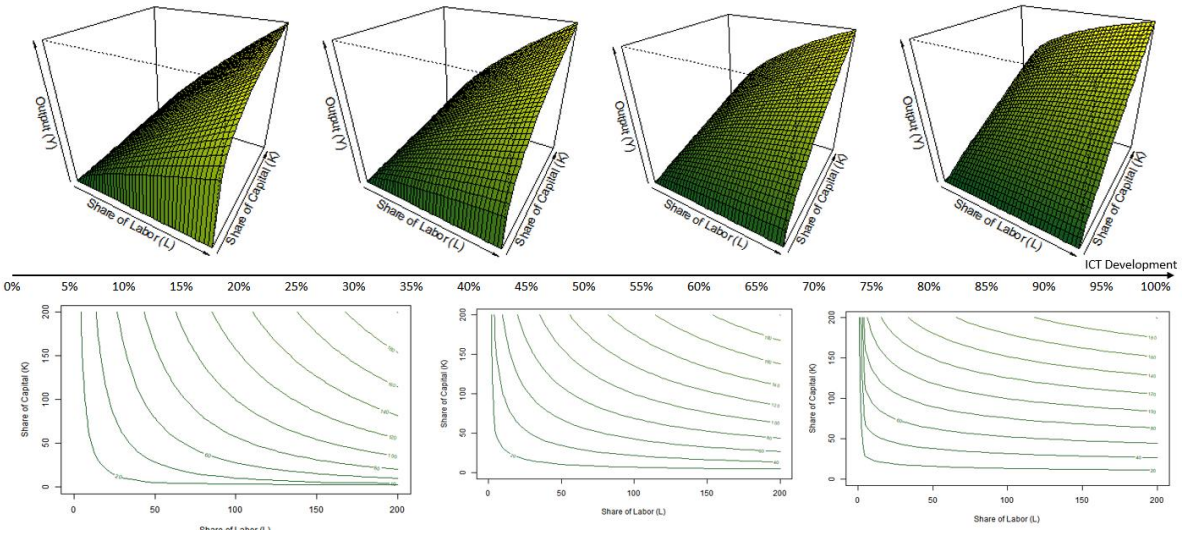


Fig 2. 4D (Y,K,L,ICT) plot of expected agricultural production evolution with the ICT development for regions with the wide support of public subsidies for ICT treatment to stimulate the output efficiency. Source: own modulation in the programming language R in the multidimensional Shiny environment

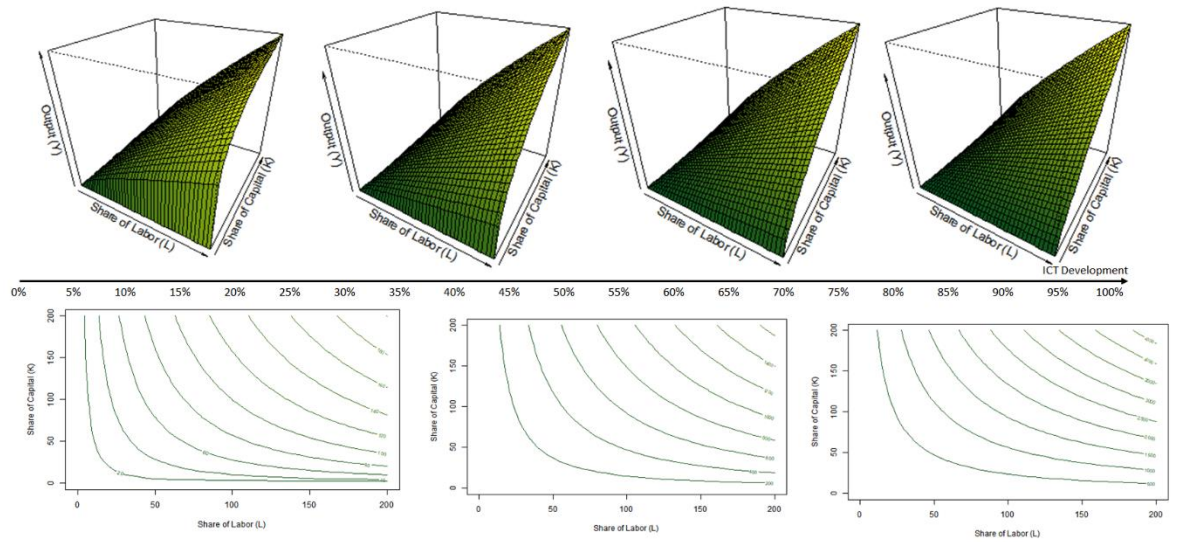


Fig 3. 4D (Y,K,L,ICT) plot of expected agricultural production evolution with the ICT development for regions with minimal subsidies to ICT treatment (like Železnohorský region, Czech Republic). Source: own modulation in the programming language R in the multidimensional Shiny environment.

The difference between the modulations represented in figures 2 and 3 reveals the fact that undeveloped regions without subsidizing cannot enjoy a significant shift in productivity (by labour) when investing in digital technologies (except for the situations with extremely high investments in ICT that are rare in relatively poor regions).

In other words, pure mathematics shows that the number of employees should not change significantly when increasing the level of ICT in farming companies in poorly developed regions without substantial subsidized support (except for the cases of possible total technological revolutions and rich investors).

Hence, such regions will be lagging in development (including implementation of the modern ICT) even more, because prosperous regions can make significantly less capital investment into ICT for gaining agricultural output increase compared to relatively poor regions (like the Iron Mts. region in the Czech Republic).

Statistical Identification Strategy: The Placebo Treatment

Placebo treatment is a relatively new topic in the research on the effects of digitalization on business models. The 21st century provides minimum opportunities for possessing exactly zero internet and computer technologies (ICT) absorption. Modern wi-fi, internet wires, special programs, and other tools become so widely distributed that farmers apply them even in the distant rural corners of the world. The Czech Republic is no exception to this rule. Czech Farmers in the Zeleznohorsky region apply digital technologies (just like farmers of thousands of similar areas on the globe). At the same time, they do not have sufficient qualifications and experience to estimate which of the top ICT provides the best results (and if it provides any significant results) to the total output compared to its costs. In this case, all the farmers of the Iron Mts. region have placebo treatment by implementing basic ICT, while most farmers (85.7%) receive real "drug". Therefore, 1/6 of all agricultural companies in the region have "placebo treatment", while 5/6 have real treatment with ICT.

This research utilizes the difference-in-differences (DiD) identification strategy (Card & Krueger, 1994; Leite, 2017). This approach demands several assumptions:

1) The randomness of treatment. The authors performed a crude validation of the data available at such a microregional level and gleaned clues about treatment contingency. Full randomness of treatment is otherwise verified using a large-scale field experiment with randomized ICT implementation, but this would include multiple types of rural microregions (i.e., not just the inner rural periphery).
    - ✓ Figures 7 to 10 in Annexes represent the overall technological treatment of companies and farmers. It is visible that although the ICT treatment is random (considering away from non-digital technologies).
    - ✓ There is no clear interconnection between the production type, legal entity status, and preferred ICT.
2) Relatively low heteroscedasticity among agricultural companies in terms of the implementation of ICT for treated and control groups.
3) The number of business units in this research represents the actual pattern within the business population in the Iron Mts. region.

The classical DiD strategy does not apply to this questionnaire without binary modification. The current state of knowledge in these statistical models proves the efficiency of the linear binary DiD estimator (Ai & Norton, 2003; Bertrand et al., 2004; Puhani, 2012).

Moreover, many prominent researchers (Athey & Imbens, 2006; Blundell & Dias, 2002; Imbens & Rubin, 2015) noted that although non-linear binary DiD estimators exist, their outcomes and the size of treatment effect are not straightforward and may impute bias on the estimation of the size of the treatment effect. The unique approach of (Karaca-Mandic et al., 2012) reduces this bias by utilizing comparison with the linear DiD estimation models. Thus, the linear binary DiD estimation model is

the basic approach for estimating the significance and the size of the treatment effect for quantitative values (like if the business model improved or if the level of ICT became higher).

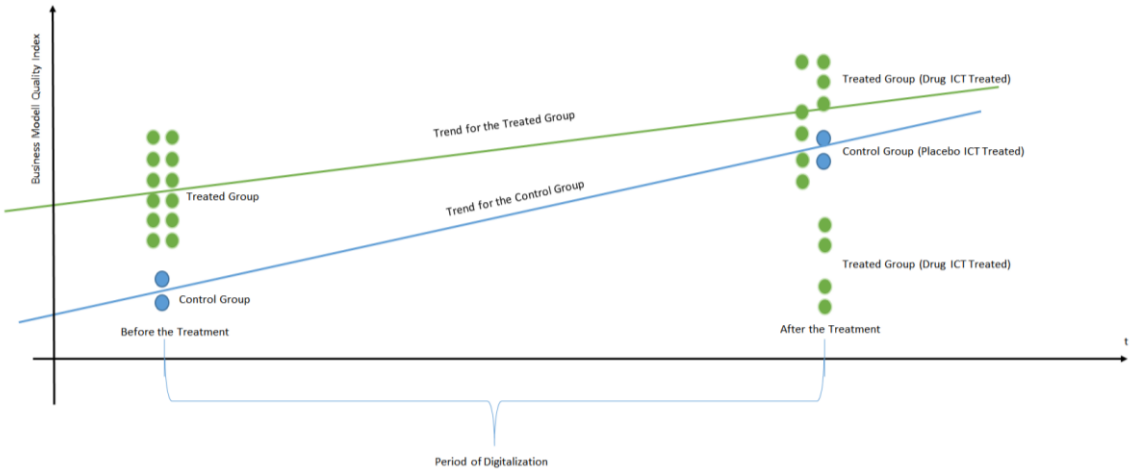


Fig 4. Overview of the outcomes in the survey in terms of the statistical identification strategy (linear DiD estimator) Iron Mts. region (selected on the chart), in % of the maximum value. Source: own elaboration

In the following section, the empirical model estimates the quantitative size and statistical significance of the ICT treatment effect for the Iron Mts. region.

The survey represents a one-time question of the respondent with the request to estimate the difference between now (after the application of digital technologies) and "then" (before the application of digital technologies). The term "before" derives from the memories and comparisons of the interviewers where they compared the benefits of the application of digital technologies before the application and after it. In this sense, this is a limitation of the applied approach, however, it can be fully accepted, because from the respondents' point of view it is better and more accurate to identify and compare the situation before and after the implementation of ICT in an ex-post assessment. Figure 4 depicts this process better.

4. Results

4.1 Results of the empirical survey

The survey of this paper focused on four areas that interact with each other, namely technology in use, financing of new technology and future investment, human resources, and supplier-customer relationships.

If we focus on technologies, then it turns out that **the use of digital technology** is relatively low (about 25% of the respondents of our empirical survey), with participants who mainly use farm management applications in combination with sensors. The topic of the use of different types of digital technologies can be clearly schematized through a network analysis of technologies implemented by farmers and enterprises in the Iron Mts. region. The usual implementation of network analysis simplifies the description of interrelationships within complex phenomena (Windolf, 2011). Network analysis can capture the overall picture of the complex processes of digital and other technology adoption across the region and provide descriptive statistics in a single graph. It represents the overall linkages between major technologies, farmers and businesses in the Iron Mountain region. The plot below represents these results (see Figure 5). The network analysis shows that farmers and legal entities are adopting different technologies. Most of them are adopting Wi-Fi and GPS. At the same time, one farmer (e5d6cdeb) implements digital technologies (Wi-Fi and GPS) and considers simple technologies (like forage packers) as connected to the digital sphere. Other farmers and companies have no misunderstanding of what digital technologies are.

The differences between LEs and NPs were reflected in the question of **funding and future investments in digital technologies**, where 50% of LEs, but only 7% of NPs, consider them. The purchase price of

technology discourages respondents from further investments. The lack of funds was cited as a problem in acquiring new technologies by half of all respondents. Especially for NPs, the price represents a significant barrier. About 7% of NPs also cited poor access to the Internet as a barrier. The quality of the connection is a necessary condition for the use of digital technologies (see e.g., Wilson & Hopkins, 2019; Salemink, Strijker & Bosworth, 2017, Pelucha & Kasabov, 2020). Either their own resources or loans served as a source of financing for these entities. At the same time, there is an obvious difference between legal and natural persons of agricultural enterprises in the ability to finance these new technologies, especially with the help of their resources or credit. To date, subsidy funds are used only to a lesser extent.

Another topic was **the impact of digital technologies on human resources**. It was found that digital technologies do not greatly affect the number of employees, the respondents' access to training, or the recruitment of new workers. Based on the results of our micro-study, it is not possible to confirm or refute the outputs of the document Effects of digitisation on the labour market in the Czech Republic and the EU (2015), according to which digitisation is to be seen in the increased rate of creation, and the disappearance of jobs. The number of employees of survey respondents remains at the same level, at least from the short-term perspective of recent years. In terms of training, legal entities either provide training on an ongoing basis (just as 47% of NPs receive ongoing training) or do not consider it necessary. The most preferred form of training for LEs and NPs is from technology suppliers, self-study of manuals and publications, and instructional videos. Training is often focused on working with the computer and computer programmes – especially the basic models of farm management programmes.

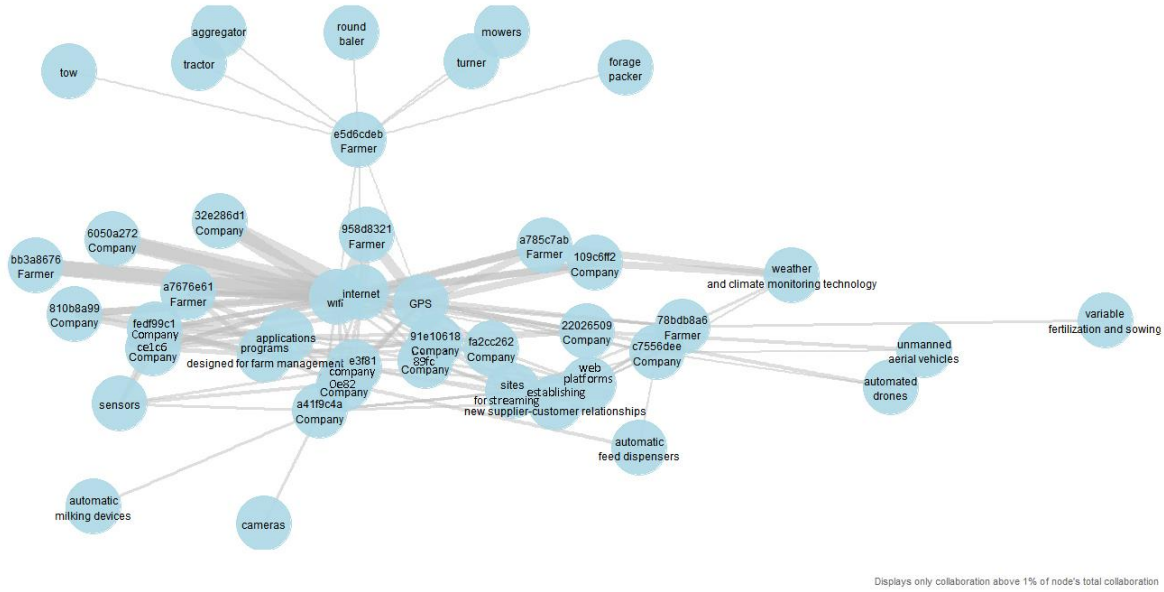


Fig 5. The network plot of all the technologies the companies and physical entities utilise in the Iron Mts. region, Czech Republic. Source: own elaboration

Notes: Own elaboration in the programming language R (network analysis of interconnections between companies, farmers, and technologies). The thickness of the lines represents the overall efforts all the employees (if any) devote to the application of each particular technology from 100% of their total production time. The plot represents the technologies/information and communication technologies the farms and companies are currently using. The more popular technology is, the closer to the centre it is; the more digitalized company or farmer is, the closer to the centre it is (except farmer e5d6cdeb – he is an outlier due to utilisation of many technologies nobody other marked in the columns related to digitalisation). The encryption technology applied hides the actual names of farmers and companies for anonymity reasons. The core network estimation algorithm (FR-networking) represents a classical analytical approach suggested by (Fruchterman & Reingold, 1991).

The approach to recruiting new workers has not changed, as entities are often unable to handpick candidates, due to a great lack of interest in working in agriculture. However, approximately 14% of respondents noted that they prefer applicants with some knowledge of agricultural technology. If we compare LEs and NPs from the perspective of IT experts, then about 70% of LEs use them. The remaining 30% of legal entities that do not have an IT expert at their disposal are the most advanced companies, and

working with these technologies is standard practice for them. On the contrary, IT experts use all NPs that use digital technologies.

Based on the results of our survey, **the impact of digitisation on supplier-customer relationships** can be assessed as minimal. Supplier-customer relationships have been affected only by the Internet, due to which supplier-customer relationships have changed quantitatively, but their structure has not changed. Even the Covid-19 pandemic did not affect this area. Although generally, it stimulated the acceleration of digitisation (see e.g., OECD, 2020), this was not confirmed among the respondents (agricultural entrepreneurs) in the territory of LAG Železnohorský Region. The pandemic had a rather negative impact, especially on investments, but on the other hand, it stimulated thinking about digital technologies.

4.2 The empirical model and results of the statistical analysis

The general linear binary DiD estimation model should estimate the significance and the size of the treatment effect of qualitative indicators (the level of the business model and its components and the development of ICT):

$$\mathbf{Y_{its} = A_{0s} + \mu 1 * If\ After\ Treatment_{it} * If\ Treated_i + \mu 2 * If\ After\ Treatment_{it} + \mu 4 * If\ Treated_i + X_{its} + \xi_{its}}$$

Notes: $\mathbf{Y_{its}}$ **–** is a particular component (s) of the general business model (Y) for a particular agricultural business unit (i) within a particular time (t); it is a dummy variable that is one when a particular component (s) improved after treatment, 0 otherwise;

$\mathbf{A_{0s}}$ – is an intercept of each particular component (s);

If After Treatment$_{it}$ – is a dummy variable representing if a particular period (t) for a particular company (i) follows after the treatment happens (1 if so, 0 otherwise);

If Treated$_i$ – is a particular dummy variable representing if some company (i) was ever treated (1 if so, 0 otherwise);

$\mathbf{X_{its}}$ **–** is an additional control component of the model (omitted if insignificant);

$\boldsymbol{\xi_{its}}$ – are residuals of the model.

The above empirical model implements components (s) of the business model (Y). Thus, it is important to note what components the business model consists of.

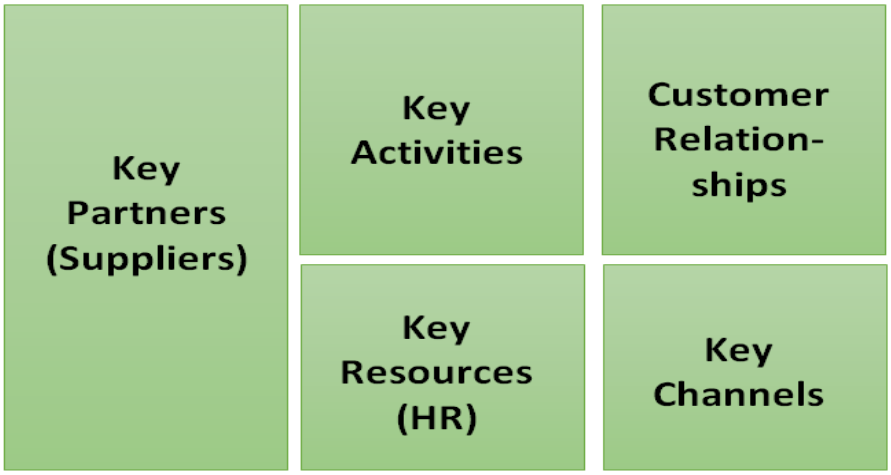


Fig 6. Overview of a classical business model of agricultural companies and core components. Notes: Own processing based on complex verification of prominent research on the elements of a business model (Drucker, 1995, 2008, 2017)

In addition, this research evaluated the study on the components of the business models for the agricultural companies that resemble the picture above too (Dörr & Nachtmann, 2022; Muller-Seitz,

2022). Adding additional parts to this scheme can be subject to critique (Breunig, 2022) because it is impossible to assess the influence of digital technologies on the cost structure and revenue stream in the field conditions (outside the perfect conditions when all the data is available).

Thus, this study verifies the influence of digital technologies on such components (S) of a business model (Y) for the companies in Iron Mts. region (i) as key partners, key activities, human resources, customer relations, and key channels (within the period t). Time has two values: before treatment, and after the treatment.

This research implements the linear binary DiD estimation as a statistical identification strategy. The table below represents these results.

Tab 1. The outcomes of the linear binary DiD estimation, robust standard errors. Source: Own elaboration in the programming language R (robust standard errors estimated from the robust variance matrixes from the "sandwich" library that provide similar results to statistical bootstrapping (Zouhar, 2022; Zouhar & Sklenicka, 2017).

	Dependent variable:				
	If_Relations_with_Suppliers_Improved	If_Relations_with_Customers_Improved	If_HR_Improved	If_Activities_Improved	If_Channels_Improved
	(1)	(2)	(3)	(4)	(5)
if_ever_treated	0.00	-0.00	0.00	-0.00*	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
if_after_treatment	0.40*	0.40*	-0.00***	0.60***	0.40*
	(0.23)	(0.23)	(0.00)	(0.23)	(0.23)
if_ever_treated:if_after_treatment	-0.11	-0.19	0.42***	0.40*	0.31
	(0.25)	(0.24)	(0.10)	(0.23)	(0.25)
Constant	-0.00***	-0.00	0.00***	0.00**	0.00**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Observations	58	58	58	58	58
R2	0.19	0.16	0.30	0.92	0.52
Adjusted R2	0.15	0.12	0.26	0.91	0.49
Residual Std. Error (df = 54)	0.34	0.31	0.33	0.15	0.34
F Statistic (df = 3; 54)	4.22***	3.48**	7.54***	198.47***	19.34***
Note:					*p<0.1; **p<0.05; ***p<0.01

Note: Two companies plus three private entrepreneurs (a total of five entities with ten observations) create the control group. Variable "if ever treated" controls the original difference between the control and treated groups. Indicator "if after treatment" holds control for the time change before and after the treatment from the words of the interviewed people (how they compare the times before and after). The index "if ever treated: if after treatment" is the interaction term that estimates the significance of the ICT treatment (clear from the time effect and original difference between the groups); it shows the probability increase for having overall improvement in each component of the business model and the statistical significance of such increase.

Peter Drucker, the world's most influential scientist in management, notes that ICT treatment in management should provide nothing more but the skills increase of employees without the improvement of the business model (Drucker, 2006, 2008, 2009, 2020). Computer technologies can only become a tool, not solutions, Peter Drucker supposes.

Generally, there is insufficient quantitative research to prove this concept (Drucker, 2006, 2008, 2009, 2020). This is just a common logic of management. Our research partially proves this concept. There is an insignificant effect of the ICT treatment on the relations with customers and suppliers. All five components of the business model prove that times became better. For example, there is a 40% chance ($p < 0.1$) for improvement in the relations with customers and suppliers for the common world technology development clear from the ICT direct treatment (purchasing of the usually expensive professional digital technologies) within 3–5 years. There is no proof to praise the modern professional digital technologies they somehow additionally increased the outcomes of these relations with suppliers and customers (extra to the overall effect in time).

At the same time, the overall level of HR capital decreased ($p < 0.05$) over the last 3–5 years (while the size of this effect is miserable while statistically significant). It can result from any effects starting from increased digital addiction and ending with the pandemic factor (additional research can potentially explain it in the future).

However, companies and private entrepreneurs who applied digital technologies enjoyed a 42% ($p < 0.01$) higher self-reported probability of higher HR development level. It is expectable, because the utilization

of more advanced ICT technologies requires better skills of employees, thus, stimulating them to increase their HR capital. For example, the implementation of the digitalized harvester demands high-level IT skills from the employees that will use it. Workers can either learn themselves (usually with the help of the employer) or leave. This microstudy shows that workers decided to learn and increase their level of HR in those business units that implemented the more advanced digital technologies (ICT treatment) compared to the placebo-treated group (control group that implemented only basic internet technologies).

On the contrary, the effect of time increased the probability of increasing business activities by 60% ($p < 0.01$) in addition to the 40% ($p < 0.1$) probability increase for the ICT-treated groups.

However, ICT treatment did not provide any significant effect on channels. This can be the outcome of the fact that companies and entrepreneurs in the Zeleznohorsky region prefer technical ICT treatment (like automatic feeders, and drones) that cannot directly improve the channels, and, at the same time, there is a general effect of stability in the structure and number of customers for agricultural enterprises. Thus, the perceived impact of ICT on these matters is significantly weaker.

The limitation of this research is a relatively low number of observations (58) for estimation of the effect. The authors applied the simplest model to avoid the overfitting problem related to the limit of this research (i.e., low number of observations). Fewer operating business units always operate in selected rural regions such as the Železnohorsky microregion. On the other hand, it should be emphasized that this research covers the representative part of operating businesses.

What are the implications of this theoretical model? The ICT treatment demands additional funding, thus, being part of the capital (not labour). At the same time, the empirical model shows that there is a probability that ICT treatment does not significantly improve the business process (except for HR and, particularly, business activities).

Suppose these components of the business models are not the core revenue-generating factors for such agricultural companies. In this case, ICT treatment is just an increase in capital cost for an insignificant shift in the output (estimated through its proxy variable: revenue). Thus, agricultural business units from poorly developed regions can regard ICT treatment as an increase in costs. The overall development of digitalization can replace the core benefits of ICT treatment just by covering basic needs. For example, people can communicate through special project management software (that can cost money), and they can use free (or almost free) technologies like mobile phones, SMS, WhatsApp, Telegram, Viber, Twitter, and many other similar technologies to conversate and, thus, improving the core business processes without a special ICT treatment.

As seen from equation 7, public subsidies can improve the performance of the capital for low-developed regions. Government is the core source of help for the development of ICT in poorly developed regions.

At the same time, this research has a limitation. There is insufficient information to judge if the development of digital technologies (ICT treatment) can guarantee the development of similar periphery rural regions (like the Zeleznohorsky microregion). For example, there are some Finnish regions with good ICT infrastructure that are relatively undeveloped (for example, Heikkilä, J.-P., personal interview, 1.11.2022; Heikkilä & Brewster, 2014). From this point of view, other factors related to digital literacy and, in particular, knowledge of the population about the possibilities of the digital economy and the virtual environment play an important role. Thus, ICT treatment cannot grant prosperity by itself, or significant benefits compared to the untreated companies from rural areas boosted by the overall progress (for example, implementation of cheaper simple combined harvester holding connection through such technology as WhatsApp, instead of more expensive robotized harvesters run by distant operators).

The theoretical model of ICT development for developed regions can be implemented using public subsidies to cover part (or all) of ICT treatment costs. Therefore, investment in additional capital (such as ICT) may yield a better outcome for the model. At the same time, research into which regions are more deserving of such subsidies (in terms of results) can be a good subject for future research, as this research focuses exclusively on the Železnohorsky region.

5. Conclusion

This paper has explored the issues related to the potential change in business behaviour of agricultural holdings and farmers, following the digitization and use of ICT. Specifically, attention was focused on the rural territory of the inner periphery of the Czech Republic, which covers the LAG Železnohorský Region with a strong rural and agricultural base. In an empirical investigation, it was confirmed that digitization has begun to have a significant impact on the functioning of agricultural enterprises, especially concerning the use of new technologies that are linked to the digitization process, which has a positive effect on the efficiency of the functioning of enterprises. However, the wider potential of these technologies in other spheres is not yet fully utilised, or the results were rather negative. The survey focused on the impact of digitisation on supplier-customer relationships, human resources, and the use of new technologies.

The above-mentioned findings and discussion of key conclusions from the conducted empirical survey, underline the importance and increasing interest of, especially, larger agricultural enterprises in new technologies, however, their potential is still not fully utilised. Legal entities (i.e., larger agricultural enterprises) generally use digital technologies to a greater extent than natural persons, which is determined by their financial capabilities.

Moreover, the empirical research provides clues that there can be no significant effect of utilizing ICT for improving the relations with suppliers and customers, and for improving the channels of distribution. Thus, ICT can raise costs without positive effects on these aspects of agricultural business in the Iron Mts. region.

However, advanced implementation of ICT provides a statistically significant chance for improving the overall level of HR (which is very intuitive, because people have to study more to implement more advanced technologies), and the business activity (which is usually measured by turnover and sales which does not automatically guarantee profitability (profitability depends on the cost structure and not just on sales) (Berk & DeMarzo, 2017; Brealey et al., 2020; Loeffler & Kruschwitz, 2005).

In addition to a basic descriptive analysis of the results of an empirical survey in a selected rural microregion, the authors of the paper developed the improved Cobb-Douglas production function (Biddle, 2021; Cobb & Douglas, 1928), which is commonly applied to a wide range of companies. The novelty of the approach lies in the fact that specific features of the agricultural sector that is the core subject to public subsidies in labour and capital are incorporated here. The agricultural sector is known as a wide receiver of public subsidies that should influence the outcomes of the overall production function by decreasing part of the cost. Moreover, the improved Cobb-Douglas production function has no place for innovative components (in our case, it is ICT treatment). Companies can apply primitive or advanced technologies that can change the overall cost-efficiency of labour and capital (that is not estimated in the classical function). This study offers a new approach by adding these components, i.e., subsidies and innovation (in our case, it is ICT treatment), into the classical model that can significantly change the overall output of the production function. Summarising the outputs of the suggested improved Cobb-Douglas production function and the results from the empirical research, it is possible to conclude that subsidies to ICT can stimulate the development of the human capital in periphery rural regions and increase the overall level cash flows coming from improved business activities (judged on the research of the Iron Mts. region). Such subsidies could reduce the overall cost structure of implementing the ICT and improve the overall background in the Iron Mts. region in these aspects.

The added value of the paper is that it created a contextual contribution to the discussion regarding the level of digitisation, and the ability to use new technologies by agricultural entities, not only in their operation but also in the broader functioning concerning the market and supplier-customer relations. Empirical verification was carried out on the territory of a rural microregion in the territory of LAG Železnohorský Region, which represents a model example of a rural inner periphery with available market towns that stabilise the settlement structure. It follows from the empirical survey that the level of digitisation of farmers is relatively low. The need for digitisation will only increase in the future, and

businesses and entrepreneurs must take a more proactive approach, and focus more on new business opportunities, otherwise, their market position may deteriorate.

The low level of digitisation of smaller agricultural entities in the surveyed area stems mainly from respondents' lack of interest in digital technologies, but also a lack of financial resources. The lack of interest, especially among natural persons, is a consequence of the fact that NPs usually have no employees – they procure everything themselves and, therefore, have little time and space with which to monitor new trends. Given that digitisation and new technologies will increasingly be reflected in the normal functioning of rural regions (e.g., in connection with the SMART village concept), this agenda should be more coordinated by representatives of local action groups, e.g., in the form of various workshops, trainings, and information events. In this way, the possibilities of the digital age should become closer to the normal functioning of, not only agricultural entrepreneurs, but also municipalities and non-profit organisations operating in the countryside. It is, therefore, evident that the prevailing "techno-optimist approach" in EU strategic planning (see Alam et al., 2018, p. 60) must be overcome by more intensive and comprehensive support for the digitisation process in rural areas, i.e., a combination of support for investments in ICT infrastructure, new technologies, digital literacy of rural stakeholders, and the strengthening of their knowledge and skills for more intensive use of the potential and possibilities of digital technologies and the virtual environment.

A higher degree of digitisation in agriculture could contribute to economic sustainability through the creation of new jobs (less manual-intensive), which will be especially interesting for younger job seekers. The evident contribution of the digitisation process to social cohesion through the population stabilisation of rural areas would be used. The literature review shows that the digitisation of agricultural management also contributes to environmental sustainability, through the use of digital technologies that reduce soil erosion, optimise the use of resources, and reduce the amount of fertilisers, which has a positive effect on the surrounding landscape. The current low level of digitisation of rural areas, i.e., not only Internet coverage but also the introduction of new technologies and their active use by rural stakeholders, represents a significant limit for the use of the future development potential of remote rural areas (e.g., the inner periphery of the state).

Acknowledgement

This work was funded by the Czech Science Foundation (GACR) under Grant 20-17810S with the title *"Rural resilience in the context of trends in urban-rural digital divide"*. Authors of this manuscript would also like to thank Dr. Matthew Copley for his proof reading and overall English edition (http://www.editmyenglish.eu/).

Academic references

[1] Ai, C. & Norton, E. C. (2003). Interaction terms in logit and probit models. *Economics Letters*, 80(1), 123–129. DOI: 10.1016/s0165-1765(03)00032-6.

[2] Alam, K., Erdiaw-Kwasie, M. O., Shahiduzzaman, M. & Ryan, B. (2018). Assessing regional digital competence: Digital futures and strategic planning implications. *Journal of Rural Studies*, 60, 60–69. DOI: 10.1016/j.rurstud.2018.02.009.

[3] Athey, S. & Imbens, G. W. (2006). Identification and Inference in Nonlinear Difference-in-Differences Models. *Econometrica*, 74(2), 431–497. DOI: 10.1111/j.1468-0262.2006.00668.x.

[4] Bai, C., Quayson, M. & Sarkis, J. (2021). COVID-19 pandemic digitization lessons for sustainable development of micro- and small enterprises. *Sustainable Production and Consumption* 27, 1989–2001. DOI: 10.1016/j.spc.2021.04.035.

[5] Berk, J. B. & DeMarzo, P. M. (2017). *Corporate Finance*. London: Pearson.

[6] Bertrand, M., Duflo, E. & Mullainathan, S. (2004). How Much Should We Trust Differences-in-Differences Estimates? *Quarterly Journal of Economics*, 119(1), 249–275. DOI: 10.2307/25098683.

[7] Biddle, J. E. (2021). *Progress through Regression: The Life Story of the Empirical Cobb-Douglas Production Function (Historical Perspectives on Modern Economics).* Cambridge University Press.

[8] Blundell, R. & Dias, M. C. (2002). Alternative approaches to evaluation in empirical microeconomics. Portuguese Economic Journal, 1(2), 91–115. DOI: 10.1007/s10258-002-0010-3.

[9] Bolfe, É. L., Jorge, L. A. d. C., Sanches, I. D., Luchiari Júnior, A., da Costa, C. C., Victoria, D. d. C., Inamasu, R. Y., Grego, C. R., Ferreira, V. R. & Ramirez, A. R. (2020). Precision and Digital Agriculture: Adoption of Technologies and Perception of Brazilian Farmers. *Agriculture* 10(12), e653. DOI: 10.3390/agriculture10120653.

[10] Bowen, R. & Morris, W. (2019). The digital divide: Implications for agribusiness and entrepreneurship. Lessons from Wales. *Journal of Rural Studies* 72, 75–84. DOI: 10.1016/j.jrurstud.2019.10.031.

[11] Brealey, R., Myers, S. & Allen, F. (2020). *Principles of Corporate Finance*, 13th ed. New York: McGraw-Hill.

[12] Breunig, P. (2022). Economic Benefit Quantification. In Dörr, J. & Nachtmann, M., eds., *Handbook Digital Farming: Digital Transformation for Sustainable Agriculture* (pp. 79–86). Berlin: Springer.

[13] Card, D. & Krueger, A. B. (1994). Minimum wages and employment: a case study of the fast-food industry in New Jersey and Pennsylvania. *American Economic Review*, 84(4), 772–793. DOI: 10.2307/2118030.

[14] Chytrý venkov – Obnova a rozvoj služeb na venkově (2018). Brussel: European Network for Rural Development.

[15] Cobb, C. W. & Douglas, P. H. (1928). A Theory of Production. *American Economic Review*, 18(1), 139–165.

[16] Cristobal-Fransi, E., Montegut-Salla, Y., Ferrer-Rosell, B. & Daries, N. (2020). Rural cooperatives in the digital age: An analysis of the Internet presence and degree of maturity of agri-food cooperatives' e-commerce. *Journal of Rural Studies* 74, 55–66. DOI: 10.1016/j.jrurstud.2019.11.011.

[17] De Clercq, M., Vats, A. & Biel, A. (2018). *Agriculture 4.0: The Future of Farming Technology*. New York: Oliver Wyman.

[18] Dörr, J. & Nachtmann, M. (2022). *Handbook Digital Farming: Digital Transformation for Sustainable Agriculture*. Berlin: Springer.

[19] Drucker, P. F. (1995). *People and Performance: The Best of Peter Drucker on Management*. London: Routledge.

[20] Drucker, P. F. (2006). *Innovation and Entrepreneurship: Practice and Principles*. New York: HarperCollins Publishers.

[21] Drucker, P. F. (2008). *Management*. New York: HarperCollins Publishers.

[22] Drucker, P. F. (2009). *Management Cases*. New York: HarperCollins Publishers.

[23] Drucker, P. F. (2017). *The Theory of the Business*. Cambridge, MA: Harvard University Press.

[24] Drucker, P. F. (2020). *Peter F. Drucker on the Network Economy*. Cambridge, MA: Harvard University Press.

[25] Fröhlich, E. & Steinbiß, K. (2020). Supplier Relationship Management Goes Digital: First Empirical Insights. *Universal Journal of Management*, 8(3), 63–73. DOI: 10.13189/ujm.2020.080303.

[26] Fruchterman, T. M. J. & Reingold, E. M. (1991). Graph Drawing by Force-directed Placement. *Software – Practice and Experience*, 21(11), 1129–1164. DOI: 10.1002/spe.4380211102.

[27] Gerhardt, C. et al. (2022). Framework for the Digital Transformation of the Agricultural Ecosystem. In: Dörr, J., Nachtmann, M. (eds). Handbook Digital Farming. Springer, Berlin, Heidelberg. DOI: 10.1007/978-3-662-64378-5_2.

[28] Heley, J. & Jones, L. (2012). Relational rurals: some thoughts on relating things and theory in rural studies. *Journal of Rural Studies* 28(3), 208–217. DOI: 10.1016/j.jrurstud.2012.01.011.

[29] Heikkilä, J.-P., Brewster, C. & Mattila, J. (2014). Micro-Political Conflicts and Institutional Issues During e-HRM Implementation in MNCs: A Vendor's View. In Machado, C. & Davim, J., eds., *Human Resource Management and Technological Challenges. Management and Industrial Engineering*. (pp. 1–22). Cham: Springer. DOI: 10.1007/978-3-319-02618-3_1.

[30] Hrustek, L. (2020). Sustainability Driven by Agriculture through Digital Transformation. *Sustainability 12*(20), e8596. DOI: 10.3390/su12208596.

[31] Ievoli, C., Belliggiano, A., Marandola, D., Milone, P. & Ventura, F. (2019). Information and Communication Infrastructures and New Business Models in Rural Areas: The Case of Molise Region in Italy. *European Countryside* 11(4), 475–496. DOI: 10.2478/euco-2019-0027.

[32] Imbens, G. W. & Rubin, D. B. (2015). *Causal Inference for Statistics, Social, and Biomedical Sciences: An Introduction*. Cambridge University Press.

[33] Ingram, J. & Maye, D. (2020). What Are the Implications of Digitalisation for Agricultural Knowledge? *Frontiers in Sustainable Food Sysems.,* 66(4). DOI: 10.3389/fsufs.2020.00066.

[34] Jäisänen, J. & T. Tuovinen, T. (2020). Digital innovations in rural micro-enterprises. *Journal of Rural Studies* 73, 56–67. DOI: 10.1016/j.jrurstud.2019.09.010.

[35] Karaca-Mandic, P., Norton, E. C. & Dowd, B. (2012). Interaction Terms in Nonlinear Models. *Health Services Research*, 47(1), 255–274. DOI: 10.1111/j.1475-6773.2011.01314.x.

[36] Klerkx, L., Jakku, E. & Labarthe, P. (2019). A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. *NJAS – Wageningen Journal of Life Sciences* 90–91 e100315. DOI: 10.1016/j.njas.2019.100315.

[37] Kouřilová, J. (2019). Role lidských zdrojů v rozvoji venkovských oblastí v rámci nových výzev digitální ekonomiky – kontext pro formování nové politiky rozvoje venkova. In*: Region v rozvoji společnosti 2019* (pp. 240–249). Brno: Mendelova univerzita v Brně.

[38] Leite, W. (2017). Propensity Score Matching. In Leite, W., ed., *Practical Propensity Score Methods Using R* (Chapter 5). Thousand Oaks: Sage. DOI: 10.4135/9781071802854.n5.

[39] Loeffler, A. & Kruschwitz, L. (2005). *Discounted Cash Flow: A Theory of the Valuation of Firms*. Hoboken, NJ: John Wiley and Sons.

[40] Machado, C. & Davim, J. P., eds. (2014). *Human Resource Management and Technological Challenges*. Cham: Springer. DOI: 10.1007/978-3-319-02618-3.

[41] Ozdogan, B., Gacar, A. & Aktas, H. (2017). Digital Agriculture practices in the Context of Agriculture 4.0. *Journal of Economics, Finance and Accounting, 4*(2), 184–191. DOI: 10.17261/Pressacademia.2017.448.

[42] Pělucha, M., Kasabov, E., eds. (2020). *Rural Development in the Digital Age: Exploring Neo-Productivist EU Rural Policy*. Abingdon: Routledge.

[43] Puhani, P. A. (2012). The treatment effect, the cross difference, and the interaction term in nonlinear "difference-in-differences" models. *Economics Letters*, 115(1), 85–87. DOI: 10.1016/j.econlet.2011.11.025.

[44] Rotz, S., Duncan, E., Small, M., Botschner, J., Dara, R., Mosby, I., Reed, M. &. Fraser, E. D. (2019). The Politics of Digital Agricultural Technologies: A Preliminary Review. *Sociologia Ruralis, 59*(2), 203–229. DOI: 10.1111/soru.12233.

[45] Saiz-Rubio, V. & Rovira-Más, F. (2019). From Smart Farming towards Agriculture 5.0: A Review on Crop Data Management. *Agronomy, 10*(2), e207. DOI: 10.3390/agronomy10020207.

[46] Salemink, K., Strijker, D. & Bosworth, G. (2017). Rural Development in the Digital Age: a systematic literature review on unequal ICT availability, adoption, and use in rural areas. *Journal of Rural Studies, 54*, 360–371. DOI: 10.1015/j.jrurstud.2019.09.001.

[47] Scott, M. (2013). Resilience: a conceptual lens for rural studies? *Geography Compass* 7(9), 597–610. DOI: 10.1111/gec3.12066.

[48] Shucksmith, M., Talbot, H. (2015). Localism and rural development. In: Divoudi, S., Madanipour, A., eds., *Reconsidering Localism* (Chapter 13). New York and London: Routledge. DOI: 10.4324/9781315818863.

[49] Sklenicka, P. & Zouhar, J. (2017). Predicting the visual impact of onshore wind farms via landscape indices: A method for objectivizing planning and decision processes. *Applied Energy*, 209, 445–454. DOI: 10.1016/j.apenergy.2017.11.027.

[50] Trendov, N. S., Varas, S. & Zeng, M. (2019). *Digital Technologies in Agriculture and Rural Areas* [briefing paper]. Rome: Food and Agriculture Organization of the United Nations.

[51] Vaishar, A., Šťastná, M. (2019). Smart village and sustainability. Southern Moravia case study. *European Countryside* 11(4), 651–660. DOI: 10.2478/euco-2019-0036.

[52] Voronin, B. A., Chupina, I. P., Voronina, Y. V., Chupin, Y. N., Zarubina, E. V. & Simachkova, N. (2020). The role of human capital in the digitalization of the country's agriculture. *EDP Sciences 176,* e05016. DOI: 10.1051/e3sconf/202017605016.

[53] Walter, A., Finger, R., Huber, R. & Buchmann, N. (2017). Opinion: Smart farming is key to developing sustainable agriculture. *PNAS, 114*(24), 6148–6150. DOI: 10.1073/pnas.1707462114.

[54] Warlow, A., Kasabov, E. (2014). Rethinking rural conflict, cooperation difficulties, and failure: the case of rural cooperatives. In: Kasabov, E., ed., *Rural Cooperation in Europe* (pp. 266–282). Basingstoke: Palgrave Macmillan.

[55] Wilson, R. & Hopkins, J. (2019). The changing shape of Scotland's dogital divide. *European Countryside, 11*(4), 563–583. DOI: 10.2478/euco-2019-0031.

[56] Windolf, P. (2011). The German-Jewish Economic Elite (1900–1933). *Zeitschrift für Unternehmensgeschichte*, 56(1), 135–162. DOI: 10.2139/ssrn.2545818.

[57] Zouhar, J. Statistical Inference [lecture]. Prague: Prague University of Economics and Business, 30. May 2022.

Other sources

[58] Agrocares (2019). *What is the difference between precision, digital and smart farming?* Available at https://agroflowsystem.com/blog/what-is-the-difference-between-precision-digital-and-smart-farming/.

[59] Brini, M. *Making Digital Agriculture "smallholder-friendly"*. ENVEVE. Retrieved from: https://www.enveve.com/making-digital-agriculture-smallholder-friendly/. Last accessed: 7th November 2022.

[60] Heikkilä, J.-P. (2022). Personal interview, 1. 11. 2022.

[61] *Strategie komunitně vedeného místního rozvoje MAS ŽR na období 2014–2020.* Heřmanův Městec: MAS Železnohorský region. Retrieved from Strategie komunitně vedeného místního rozvoje MAS ŽR – MAS Železnohorský region (zeleznohorsky-region.cz). Last accessed: 7th November 2022.

[62] Ministry of Agriculture (2022). MAS Železnohorský region, z.s. – (selection on the map). Praha: Ministry of Agriculture of the Czech Republic. Available at: https://eagri.cz/public/app/lpisext/lpis/verejny2/plpis/.

[63] *Dopady digitalizace na trh práce v ČR a EU.* Praha: Úřad vlády ČR. Retrieved from https://www.vlada.cz/assets/evropske-zalezitosti/analyzy-EU/Dopady-digitalizace-na-trh-prace-CR-a-EU.pdf. Last accessed: 7th November 2022.

[64] *COVID-19 and the food and agriculture sector: Issues and policy responses.* Paris: OECD. Available at: https://www.oecd.org/coronavirus/policy-responses/covid-19-and-the-food-and-agriculture-sector-issues-and-policy-responses-a23f764b/. Last accessed: 7th November 2022.

[65] Oracle (2021). *What is IoT?* Available at: https://www.oracle.com/cz/internet-of-things/what-is-iot/. Last accessed: 7th November 2022.

Annex:

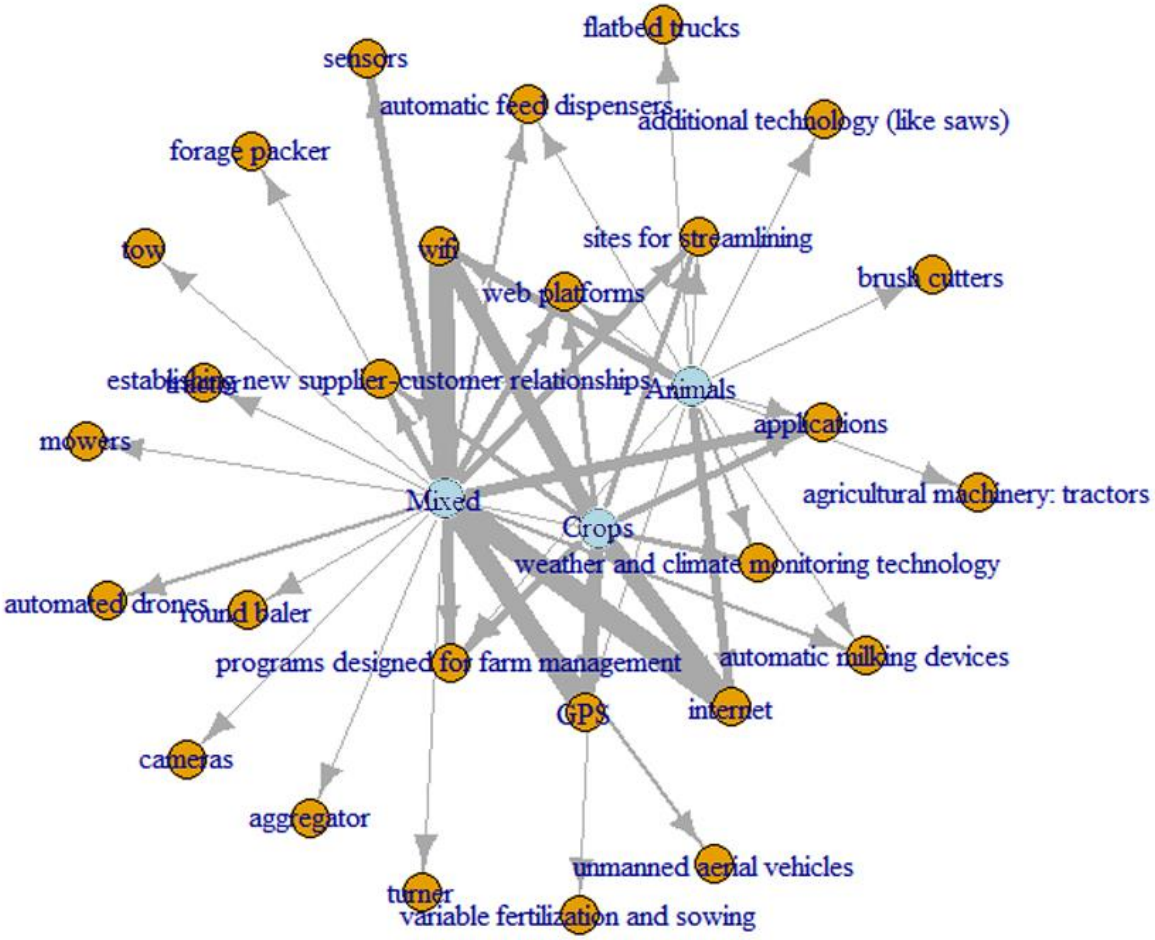


Fig 7. The network plot of all the technologies the companies and physical entities utilise in the Železnohorský region (Czech Republic) by the production type.

Notes: Own elaboration in the programming language R (network analysis of interconnections between companies, farmers, and technologies). The thickness of the lines represents the overall percentage of companies and farmers that utilize this technology in the local region. The blue colour marks companies and farmers of different types; the orange colour represents the technologies in use. The arrows mean attention paid by companies and farmers of different production type to specific technologies. The core network estimation algorithm (FR-networking) suggested by (Fruchterman & Reingold, 1991).

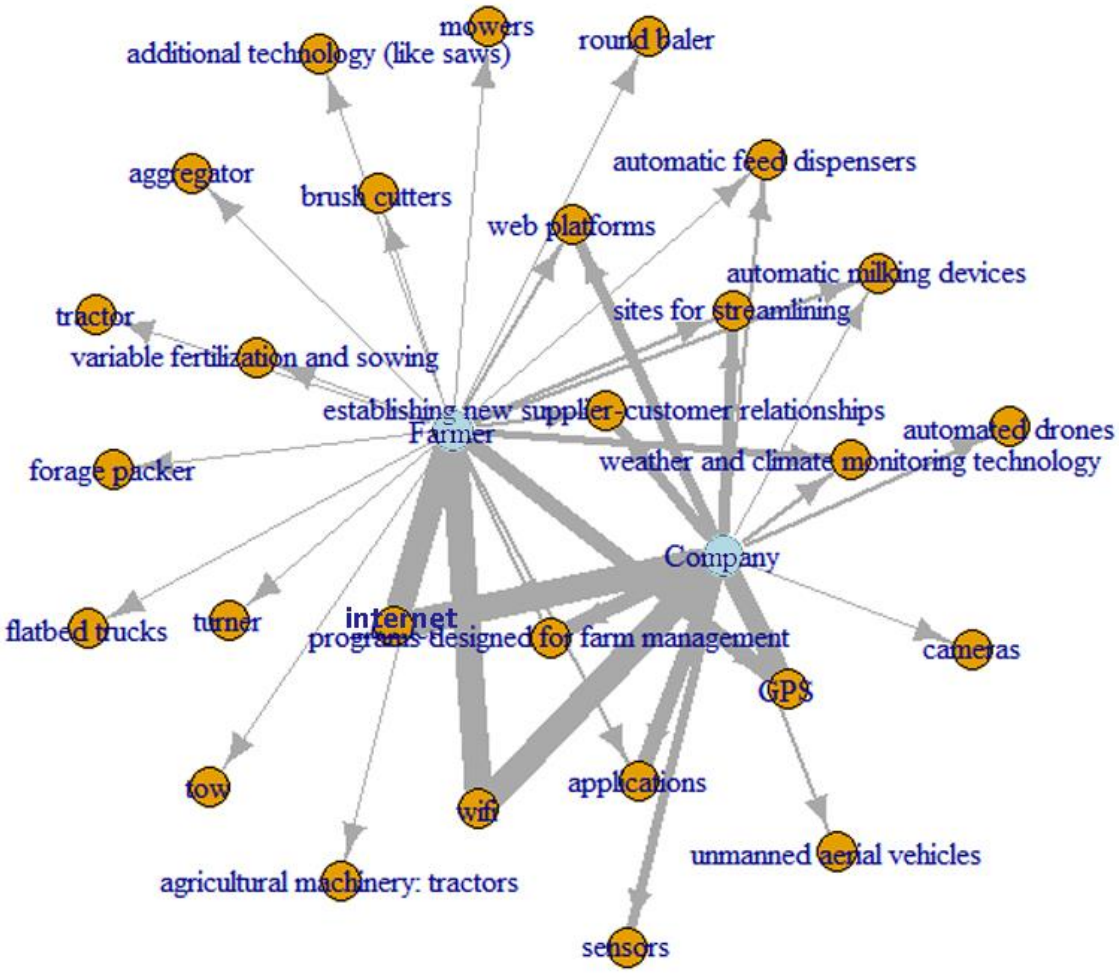


Fig 8. The network plot of all the technologies that utilize companies and physical entities in the Železnohorský region (Czech Republic).

Notes: Own elaboration in the programming language R (network analysis of interconnections between companies, farmers, and technologies). The thickness of the lines represents the overall percentage of companies (marked as "Company") and farmers (marked as "Farmer") that utilize this technology in the local region. The blue colour marks companies and farmers of different types; the orange colour represents the technologies in use. The arrows mean attention paid by companies and farmers to specific technologies. The core network estimation algorithm (FR-networking) suggested by (Fruchterman & Reingold, 1991).

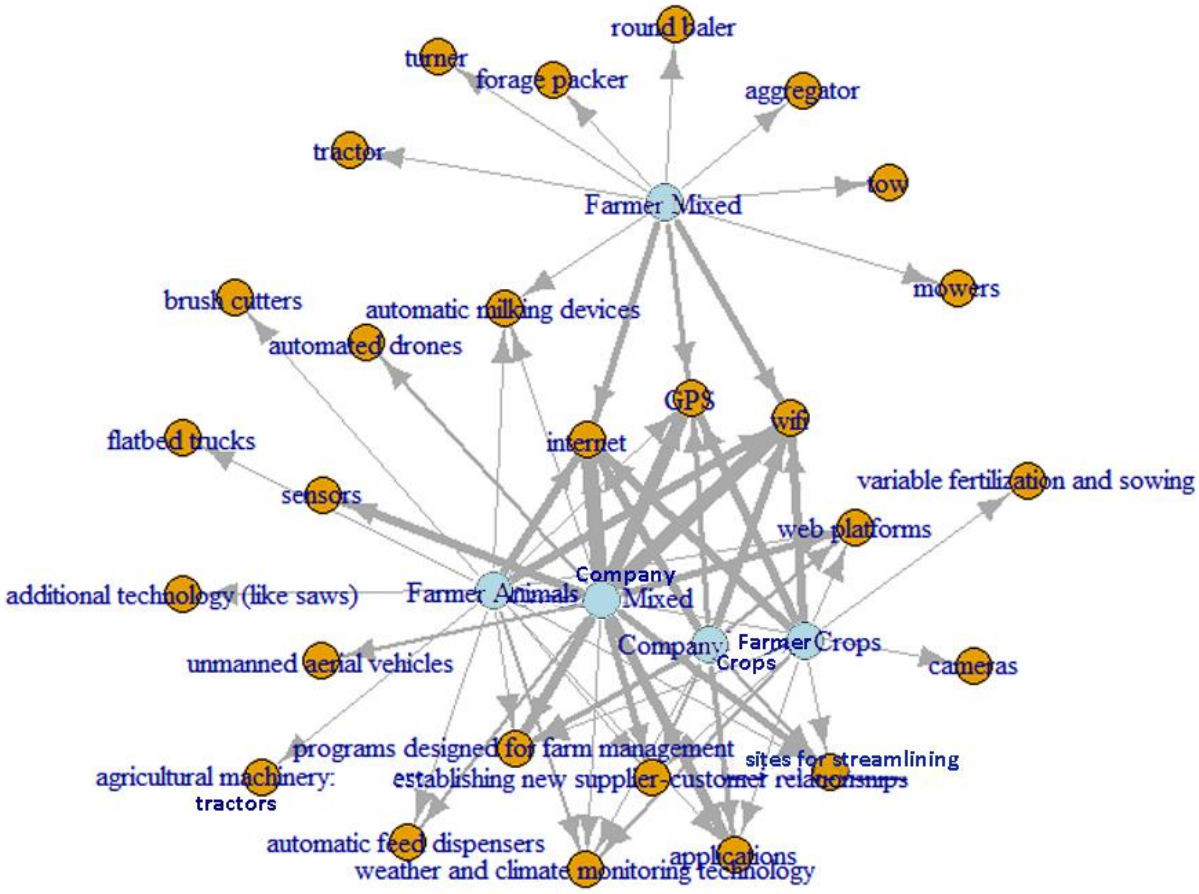


Fig 9. The network plot of all the technologies that utilize companies and physical entities in the Železnohorský region (Czech Republic).

Notes: Own elaboration in the programming language R (network analysis of interconnections between companies, farmers, and technologies). The thickness of the lines represents the overall percentage of companies (marked as "Company") and farmers (marked as "Farmer") that utilize this technology in the local region by their production structure: animal husbandry (marked as "Animals"), crops (marked as "Crops"), and mixed (marked as "Mixed"). The blue colour marks companies and farmers of different types; the orange colour represents the technologies in use. The arrows mean attention paid by companies and farmers to specific technologies. The core network estimation algorithm (FR-networking) suggested by (Fruchterman & Reingold, 1991).

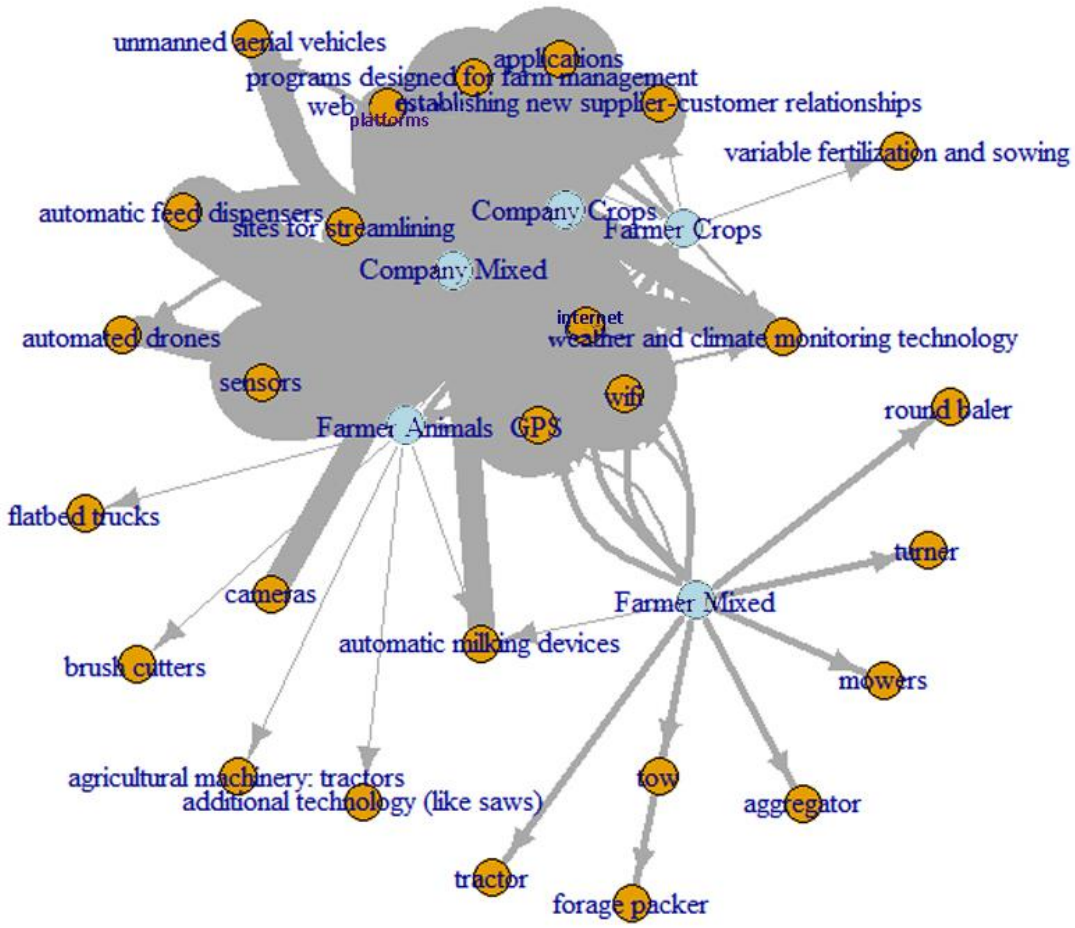


Fig 10. The network plot of all the technologies that utilize employees of all companies and physical entities in the Železnohorský region (Czech Republic).

Notes: Own elaboration in the programming language R (network analysis of interconnections between companies, farmers, and technologies). The thickness of the lines represents the overall percentage of employees in companies (marked as "Company") and farmers (marked as "Farmer") that utilize this technology in the local region by their production structure: animal husbandry (marked as "Animals"), crops (marked as "Crops"), and mixed (marked as "Mixed"). The blue colour marks companies and farmers of different types; the orange colour represents the technologies in use. The arrows mean attention paid by companies and farmers to specific technologies. The core network estimation algorithm (FR-networking) suggested by (Fruchterman & Reingold, 1991).