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Digital technologies as a driver of resilience and institutional transformation: The case of Ukrainian agroholdings

RESEARCH ARTICLE

Taras Gagalyuk[a]ⓘ and Maryna Kovalova[b]

[a]*Senior researcher, Leibniz Institute of Agricultural Development in Transition Economies (IAMO), Theodor-Lieser-Str. 2, 06120 Halle (Saale), Germany*

[b]*Director, AgriTech Market Development LLC, Vatslava Havela Blvd. 8, 03124 Kyiv, Ukraine*

Abstract

The present paper explores how implementation of digital technologies (DTs) assists firms in transition economies in addressing weaknesses of the institutional environment surrounding them, in particular via establishment of collective governance systems. Based on case studies of three large-scale agroholdings operating in Ukraine, the paper aims to fill the research gaps with regard to the following: motivation of the firm to initiate DT-enabled collective governance systems; the rules these systems are based on; and the reasons behind the firm's choice of a particular governance mode – closed, shared or open – for these systems. The findings generally support the institutional theory argument that complex technology enables coordination of exchange relationships not only within but also outside firm boundaries. At that, the choice of a governance mode between closed, shared or open institutional infrastructure is likely to depend on the firm's ownership concentration, corporate transparency, availability of resources and social embeddedness.

Keywords: agroholdings, case studies, digital technologies, institutional infrastructure, Ukraine
JEL-codes: O13, O32, Q16, Q55, Q12, Q15, D02, D23, D25, M11, M14

ⓘ Corresponding author: gagalyuk@iamo.de

1. Introduction

The rise of large-scale horizontally and/or vertically integrated agroholdings operating millions of hectares of farmland in emerging and transition economies is well documented (Gagalyuk *et al.*, 2021). Studies on the development of these huge business group-like structures in the agriculture of Eastern Europe, Latin America and other parts of the world have attempted to explain the reasons behind their viability over the past two decades. The early literature on agroholdings has maintained that such large corporate enterprises may be efficient only by opportunistically capitalizing on the voids present in their predominantly weak institutional environments (Koester, 2005). More recently, this view has been extended by the organizational resilience argument (Castellacci, 2015), according to which agroholding affiliation provides a safe (and more efficient) haven for enterprises also in the process of gradual improvement of institutional frameworks, in particular those relating to agricultural factor markets (Gagalyuk and Valentinov, 2019).

However, seemingly, both perspectives have failed to give a full account of the reasons for long-lasting viability of agroholdings as the role that agroholdings themselves are playing in the processes of institutional change and market development has been paid little attention. The above literature streams have generally followed the logic of the transaction cost theory (Williamson, 1985) and laid a major focus of inquiry on the efficiency-driven local institutional arrangements (Brousseau and Raynaud, 2011) between agroholdings and their stakeholders. Along these lines, agroholdings have been shown to relatively easily access outside capital and engage in various independent and collaborative strategies (Dorobantu *et al.*,2017) to reduce agency and other institutional costs induced by a variation in their immediate institutional environment (Gagalyuk *et al.*, 2021). These strategies involve activities such as vertical integration, corporate social responsibility initiatives, voluntary commitments to third-party disclosure and certification standards, as well as lobbying activities (Matyukha *et al.*, 2015; Visser *et al.*, 2019; Hajdu *et al.*, 2021).

Studies from sectors other than agriculture have shown that such local institutional arrangements of firms have the potential to transform into more generic ones shaping and benefitting the institutional environment as a whole (Brousseau and Raynaud, 2011). With respect to the institutional arrangements of agroholdings, still little is known about their potential to contribute to the market development and improvement of a generic institutional environment in the agriculture of transition and emerging economies. Accordingly, from the practical perspective, the potential of these arrangements to eventually become general rules governing the sector to the benefit of an extensive set of actors is still unclear. From the theoretical perspective, our understanding of the role of the firm in the processes of institutional change remains incomplete.

The present paper aims to fill these gaps at least partly. It contributes to the growing body of literature (e.g. Castellacci, 2015; Dorobantu *et al.*, 2017; Gagalyuk *et al.*, 2021; Gatignon and Capron, 2023) that extends the above views on the development and role of business groups by positing that the ability to adapt to existing institutional weaknesses alone is insufficient to explain why agroholdings proliferate. An additional focus on the agroholdings' capacity to transform and strengthen the environment they operate in is needed to complement our understanding of agroholdings' viability. More specifically, we suggest that agroholdings evolve not only due to their propensity for internalization of uncertain transactions (institutional voids perspective) or accessing larger pools of resources and superior capabilities (organizational resilience perspective), but also because of their ability to build market-based institutions and shape the institutional environment by proactively addressing a broad spectrum of stakeholders.

One striking example of such transformative activities of agroholdings may be the implementation of digital technologies (DTs). Empirical evidence from one of the global breadbaskets, Ukraine, suggests that local agroholdings are widely using various precision farming tools and customized IT solutions to integrate the obtained data into enterprise management and thereby improve own efficiency and productivity (Gagalyuk *et al.*, 2022). Recent research suggests that a wide adoption of DTs may generate positive impacts also beyond organizational boundaries, as it entails data-, knowledge- and infrastructure-sharing activities that do not

seem to benefit organizations alone (see e.g. Hinings *et al*., 2018). The question that arises in this respect is whether the use of DTs by agroholdings may result in establishing institutional infrastructures that empower and benefit a broader set of actors.

In this context, the emerging idea of the firm as an architect of open institutional infrastructures (Dubois *et al.*, 2019; Gatignon and Capron, 2023) is particularly relevant as it extends several established notions. For example, to date, there has been a broad agreement that institutional arrangements seek to lower institutional costs for a focal firm while leaving unchanged or increasing institutional costs for other actors (Dorobantu *et al.*, 2017). Recent evidence, however, complements this view and suggests that focal firms engage in the establishment of open institutional infrastructures that benefit not only a focal firm alone or even first, but also and rather the other actors in the environment surrounding the focal firm. Examples of such open institutional infrastructures include commercial skill development and professional trainings among rural population (Gagalyuk *et al.*, 2018) as well as various ecological, social and community development initiatives (Gatignon and Capron, 2023).

Yet, to date, it is not fully clear what motivates the firm to initiate such collective governance systems. If there are no recognizable pecuniary benefits, then what are the reasons behind the firm's decision to invest in such systems? What rules are these systems based on? Last but not least, what defines the firm's choice of a particular governance mode, i.e. closed, shared or open (Gatignon and Capron, 2023), for institutional infrastructures? The present paper aims to answer these questions by studying the DT-driven institution-building activities among Ukrainian agroholdings.

The paper makes the case that technological progress not only gives a boost to efficiency improvements amid problems of an institutional environment but also facilitates the emergence of governance instruments that contribute to market development via improvement of the institutional environment. These governance mechanisms will be shown to play an enabling role in the operation of agricultural business group-like structures, also known as agroholdings. Based on case studies of three of such agroholdings operating in Ukraine with different types of interactions with stakeholders such as land lessors, employees, suppliers and competitors, the paper describes i) how these interactions are governed by DT-enabled institutional infrastructures, ii) what motivates agroholdings to establish such infrastructures, and iii) how these infrastructures develop over time from locally designed arrangements toward broader market-based institutions.

The paper is structured as follows. We first elaborate on the empirical context by describing how agroholdings as an organizational form of agricultural production have evolved in Ukraine. Subsequently, we present the results of the case studies demonstrating how DTs assist the agroholdings under scrutiny in establishing and maintaining closed, shared and open institutional infrastructures. Finally, we discuss the results and research limitations and conclude.

2. The context: development of agroholdings in Ukraine

An agroholding refers to an organizational form that consists of a mother company that controls dozens or hundreds of horizontally integrated farms and manages thousands or even millions of hectares of farmland (Ostapchuk *et al.*, 2021b). Apart from huge size, agroholdings are (often) characterized by vertical integration and improved access to outside capital (Gagalyuk *et al.*, 2021b), often through political connections (Matyukha et al., 2015). Given that the degree of ownership concentration and corporate governance among agroholdings differ (Tleubayev *et al*., 2021), one can distinguish between various types of agroholdings based on these criteria. For instance, Kuns and Visser (2016) suggest to differentiate between "oligarch-led" and "investor-led" agroholdings based on the corporate governance model adopted. The first type of companies has only a minority of shares traded on a stock exchange, while the bulk of the ownership remains in the hands of the founder of the company or an entity controlled by the founder. For 'investor-led' companies, most shares are in free-float trading (cf. Hermans *et al*., 2017, p. 177).

In Ukraine today, agroholdings play an important role in agricultural production and land use. As of 2019, there were about 120 agroholdings each operating more than 10 000 hectares (Latifundist.com, 2020). From 2005 to 2018, these agroholdings have managed to grow their operated land area 3.5 times, to nearly 6 million hectares, or 29% of the entire farmland in use of commercial farms (UCAB, 2019). The largest agroholdings in terms of land area, such as Kernel and Ukrlandfarming, operate about 500,000 hectares of farmland each (Latifundist.com, 2020). Furthermore, agroholdings account for approximately one fifth of total crop production and one third of total livestock production in Ukraine today (Ostapchuk *et al.*, 2021a).

The proliferation of agroholdings in Ukraine was facilitated significantly by the developments on the world markets. Motivated by the increasing international demand, there was a twofold increase of the prices of agricultural commodities from 2006 to 2008 and a further growth of prices to this high level until 2013 after a short-term decline caused by the 2008 economic crisis (FAO, 2020). Among other things, this tremendous price growth made agricultural production a highly profitable industry, particularly in the crop sector. For example, Ukraine's sunflower production has maintained an average profitability of over 20% throughout the preceding twenty years, with some years recording a noteworthy high of 80% (Gagalyuk *et al.*, 2022). The enhanced profitability levels in agriculture have motivated inflows of capital from outside of agriculture, facilitating investments in modern production technologies and business expansion to capitalize on the productivity improvements and economies of size (see Table 1), respectively. The attractiveness of agroholdings for external investors has been then further reinforced by their large sizes, which in turn have led to the concentration of market power and favorable access to land (Graubner *et al.*, 2021).

Positive developments on the global agricultural markets were not the sole driver of the expansion of agroholdings. The institutional environment in Ukraine has also significantly contributed to the development of this business group-like form of organization of agricultural production. In general, there are two competing views that can be considered as feasible explanations of the persistence of business groups in emerging and transition economies.

First is the so-called institutional voids perspective, according to which business groups play an important function for economic development by providing necessary infrastructures when factor market institutions are weak, thus filling institutional voids (Castellacci, 2015). In this context, Ukrainian agroholdings have been shown to outperform non-holding agricultural enterprises in getting access to financial capital, in particular on international capital markets, thus obviating the problem of inefficient local financial markets and credit institutions (Gagalyuk and Valentinov, 2019). Agroholdings have been shown also to address the problem of weak supply of qualified labor, i.e. inefficient labor markets, through the organization of own qualification improvement courses for the employees (Gagalyuk and Valentinov, 2019). In addition, agroholdings have been found to employ more people per hectare and cow and to pay, on average, 18% higher salaries to their employees than non-agroholding farms (Gagalyuk and Schaft, 2016). Furthermore, by means of broadly implemented rural community development programs, agroholdings in Ukraine have been able to successfully deal with ongoing land market imperfections that emerged as a result of land reforms in early 2000's. These imperfections included (and still include) i) an atomistic structure of land ownership consisting of millions of smallholder landowners and ii) land lease as the only possible (and highly insecure) way to use land for agricultural enterprises. The latter is due to the official moratorium on farmland sales that is subject to be gradually lifted in 2021–2024 (Gagalyuk *et al.*, 2022).

Another view, a so-called organizational resilience perspective, suggests that business groups are more resilient than standalone firms not only when institutions are poor but also when the quality of institutions improves (Castellacci, 2015). This is the consequence of two distinct effects: an efficiency effect, according to which groups have greater incentives to restructure and become more efficient during market transition; and a cumulativeness effect, according to which groups also have superior resources and capabilities to exploit the new opportunities provided by the market development process (cf. ibid: 46). With regard to the efficiency effect, agroholdings have been reported to design new approaches to corporate governance and

Table 1. Land use, vertical integration and outside capital of 10 largest agroholdings of Ukraine, 2018.

Company name	Land area (×1000 ha)	Specialization (crop/livestock, %)	Processing and other businesses	Outside capital
Ukrlandfarming	570.0	85/15	Egg products, sugar, feedstuffs, storage and export infrastructure	Listed on AIM (Alternative Investment Market, a sub-market of the London Stock Exchange), loans from Deutsche Bank
Kernel	550.0	92/8	Sunflower oil, storage and export infrastructure	Listed on Warsaw Stock Exchange (WSE)
Agroprosperis Group	400.0	97/3	Feedstuffs, cereals, flour, storage and export infrastructure	Equity fund NCH (New Century Holdings) Capital
MHP	370.0	27/73	Meat products, feedstuffs, biogas, retail, storage and export infrastructure	Listed on London Stock Exchange (LSE), loans from International Finance Corporation (IFC), European Bank for Reconstruction and Development (EBRD)
Astarta	250.0	88/12	Sugar, feedstuffs, biogas, storage and export infrastructure	Listed on WSE, loans from IFC
Continental Farmers Group	165.0	99/1	Seed production, storage and export infrastructure	Formerly listed as Mriya on Frankfurt Stock Exchange (FSE), loans from IFC, EBRD, US EXIM; currently owned by Saudi Arabia's agriculture and livestock investment company (SALIC)
HarvEast	127.0	85/15	Feedstuffs, seed production, storage and export infrastructure	System Capital Management – energy and metallurgical holding owned by Rinat Akhmetov; Smart Holding owned by Vadim Novinskiy
IMC	123.9	90/10	Feedstuffs, storage and export infrastructure	Listed on WSE, loans from IFC, EBRD
Epitsentr Agro	121.4	90/10	Storage and export infrastructure	Construction chain Epitsentr K owned by the Gerega family
Ukrprominvest	116.5	93/7	Sugar, cereals, feedstuffs, retail, storage and export infrastructure	Equity fund associated with former President Poroshenko

Source: Latifundist.com (2020), UCAB (2019), company websites.

transparency that address persistent agency problems. Especially, publicly listed agroholdings in Ukraine have been found to deploy instruments such as diverse executive boards, independent auditing and disclosure of information on ownership and financial aspects, which altogether function as protective mechanisms against obscure operational practices commonly encountered in transitional economies (Gagalyuk *et al.*, 2021). As regards the cumulativeness effect, Ostapchuk *et al.* (2021a) have shown how Ukrainian agroholdings make use of more open and competitive markets not only via acquiring less competitive farms but also by making these farms more efficient through complex resource reconfiguration processes.

However, recent evidence suggests also that there is a need for an extended view that would augment the abovementioned perspectives with regard to the interactions of agroholdings with their institutional environment. In particular, the arrangements that agroholdings design to reduce the costs resulting from incomplete institutional frameworks often go beyond their immediate exchange partners, e.g. landowners, employees and shareholders. These arrangements involve cross-sector partnerships that benefit and empower not only agroholdings and their direct stakeholders, but also a broader set of actors.

For instance, several agroholdings have established long-term partnerships with (state-owned) universities to improve and modernize their curricula and provide practical trainings to agricultural students that not necessarily will become the employees of these agroholdings in the future (Agrokebety, 2023). Furthermore, in cooperation with non-governmental organizations and communal authorities in rural Ukraine, several agroholdings have introduced the programs of entrepreneurship promotion that include financial and advisory support to business start-ups that are completely independent of these agroholdings (Gagalyuk *et al.*, 2018). Moreover, agroholdings increasingly engage in the establishment of mutual exchange and creation of a culture of open dialogue to raise awareness of problems that persist in the business environment. These initiatives involve the use of various communication instruments ranging from regular meetings with rural communities to introduction of chat bots that collect individual requests from rural population (Gagalyuk *et al.*, 2021). In the context of Ukraine, where a low level of general cooperativeness persists among farm stakeholders, this approach serves as an essential step forward in the promotion of private initiative and the formation of civil society (cf. Gagalyuk *et al.*, 2021: p. 730).

The above developments point to the establishment of what Gatignon and Capron (2023), arguing along the lines of Elinor Ostrom's principles of polycentric governance, refer to as shared and open institutional infrastructures. In contrast to a closed institutional infrastructure that primarily benefits a focal firm engaging with key stakeholders on an instrumental basis, shared and open institutional infrastructures are designed for the benefit of a broader set of participants. A shared institutional infrastructure emerges when a firm joins public or nonprofit initiatives to improve existing institutional infrastructure for the benefit of a broader set of participants who share access to it. In turn, when the firm builds an open institutional infrastructure, it invests in a pool of resources widely accessible beyond its exchange partners and empowers other actors within multilateral cross-sector partnerships (cf. Gatignon and Capron, 2023: pp. 48–49).

Another, more recent, example of such transformative activities of agroholdings is the implementation of digital technologies (DTs). Empirical evidence from Ukraine suggests that local agroholdings have been and are widely using precision farming tools and customized IT solutions to improve own efficiency and productivity (Gagalyuk *et al.*, 2022). However, as the present paper shows, adoption of DTs generates positive impacts also beyond the agroholdings' own needs, as it entails data-, knowledge- and infrastructure-sharing activities that do not seem to benefit these agroholdings alone. In what follows, the paper presents the results of three case studies of Ukrainian agroholdings to show how DTs assist these agroholdings in establishing shared and open institutional infrastructures in addition to the use of DTs for the agroholdings' own benefit.

3. Case studies

The case study analysis is based on data collected during in-depth interviews with corporate managers (see Table 2) of Grain Alliance, Continental Farmers Group and Astarta. In the process of selection of agroholdings for our analysis, we aimed to choose the agroholdings that not only belong to the largest and most transparent agricultural companies in Ukraine, but also make substantial investments in the implementation of DTs in various segments of their operations. Thus, we aimed to find the agroholdings that use DTs not only in agricultural production but also in the spheres of land management, human resource management, logistics, machinery, inventory management, planning, reporting and others. For that purpose, we have used the information from various mass media portals, such as Aggeek.net (2023) and Latifundist.com (2023a,b) and consulting publications (e.g. Agrohub, 2019). Based on these sources, we have initially selected

Table 2. Characteristics of studied agroholdings.

	Company name		
	Grain Alliance	**Continental Farmers Group**	**Astarta**
Managers interviewed	Evgeniy Zaglada, Chief Financial Officer	Yevhen Korniienko, Head of Field Agronomic Monitoring Department Nonna Shmidik, Head of PR and Social Projects	Nataliia Bogacheva, Director at AgriChain Ruslan Trufanov, Head of Sales Department Yuliya Bereshchenko, Sustainable Business Development and IR Director Lilia Marachkanets, Head of Corporate Partnership and Communications Department
Land use (2022)	57 000 ha	195 000 ha	220 000 ha
Number of employees	1044 (as of 2021)	2400 (as of 2021)	6500 (as of 2022)
Revenues (2022)	EUR 55 million	n.a.	EUR 510 million
Production portfolio (main crops or animal products)	Corn Soybeans Sunflower Winter wheat Grain storage – 7 units, 330 000 tons Cattle farming	Corn Soybeans Sunflower Winter wheat Grain storage – 474 500 tons, 5 elevators Seed production – 420 tons per day Potato – storage capacity 106 200 tons, 2 plants + potato processing plant	Crop production (wheat, corn, rapeseed, soya, sunflower); Seed production – 2 plants; Sugar production: No.1 producer in Ukraine with 250 000–500 000 tons of sugar production p.a.; Cattle farming: No.1 producer of industrialized milk in Ukraine with 100 000 tons of milk production p.a. and 22 000 heads of cattle; Soybean crushing: No.2 in soybean processing in Ukraine with a crushing capacity of 230 000; Bioenergy: designed daily capacity of 150 000 m^3 of biogas
Major areas of DT application	Crop production Land management Operational management (Enterprise Resource Planning)	Crop production Land management Machinery and equipment management	Crop production Land management Machinery and equipment management Logistics
CSR expenditure (2022)	EUR 105 000	EUR 1.6 million	EUR 14.8 million

Table 2. Continued.

Major stakeholders	Local communities Investors Employees Society	Local communities Investors Society Employees	Local communities Employees Society
ESG goals	Reduction of soil exhaustion Increase the share of renewable fuels	Reduction of soil exhaustion Carbon farming/green economy	Organic farming
Ownership structure	BZK GRAIN ALLIANCE AB (Sweden) – 100%	AGRO LV LIMITED LLC (identification code 34943719) CFG TRADING LLC (identification code 39675472) MRIYA SERVICE LLC (identification code 38554271) Exact shares not available	The family of Viktor Ivanchyk (the CEO) – 40.0% of total shares outstanding through Albacon Ventures Limited Fairfax Financial Holdings Ltd – 29.9%. Free float on Warsaw Stock Exchange held mainly by Polish institutional investors, EU and US investment companies – 30.1%

Source: interviews with managers, company websites and annual reports.

10 agroholdings that met our criteria. After an initial outreach to these companies, only three out of the ten contacted agroholdings have agreed to be interviewed for the purposes of this study.

The selected agroholdings are joint stock companies with different degrees of foreign capital in the ownership structure and belong to the top 25 agroholdings-land users in Ukraine. The interviews with the managers were conducted online (and recorded upon agreement with the respondents) in February-April 2023. The obtained data were further complemented with archival information from available company documents, such as annual financial and nonfinancial (sustainability) reports, presentations for investors and company websites. Unfortunately, we have not been able to interview the stakeholders of agroholdings, such as landowners, small farmers or policymakers, due to the ongoing Russian invasion of Ukraine that complicated communication with these groups of respondents. This issue is addressed in greater detail in the description of research limitations and impact of war in the concluding section of the paper.

3.1 Grain Alliance

- *Company information*

Grain Alliance is now an agricultural production company with more than 20 years of experience although, initially, it was set up as a business providing tillage services for agricultural producers. The company was founded in 1998 by the American entrepreneur Alex Oronov as The Harvest Moon East Ltd. Initially, the company has farmed two thousand hectares of leased land and has grown in terms of both land area and product portfolio since then. By 2008, the total area operated by the company reached more than 27 000 ha. Currently, the agroholding controls around 57 000 ha of farmland, of which 54 000 ha are being cultivated, while further expansion is a part of the company's strategy (Grain Alliance, 2023b).

In 2008, the original company joined forces with a Swedish-Ukrainian team of entrepreneurs and created a new business entity called Grain Alliance. The headquarters of the holding is in Stockholm, but all operational activity is located in Ukraine, approximately 80 km to the east from Kyiv. The structure of the company is rather simple and transparent: the Sweden-based holding company Grain Alliance is the 100% owner of the Ukrainian subsidiaries. There are no intermediaries or separate management companies, as the company is managed by an elected board and an executive management team.

Following the merger of 2008, the newly established company received additional financial resources and organizational expertise for the introduction of new business practices and restructuring of existing operations. Additional capital allowed for the purchase of new agricultural equipment.

Today the company produces a balanced mix of crops and pays particular attention to the crop alteration and soil recovery processes (Grain Alliance, 2023b). Agricultural production is divided into five regional clusters each cultivating from 8000 to 12 000 ha. All the clusters are equipped with modern agricultural machinery, and the short distance between them enables more efficient usage of the machinery. The company also has four grain elevators, three of which have direct railroad access, which simplifies the logistics. The product portfolio of the company includes production of grain and oil crops, services for the reception, processing and storage of grain, and dairy farming. According to the company's annual report, it generated a net profit of about EUR 115 million in 2022. Its total number of employees in 2022 exceeded 1000 (Grain Alliance, 2023a).

■ *DTs and closed institutional infrastructure*

Grain Alliance implements modern DTs for production, management and land cadaster purposes. The approaches to technology and soil cultivation in Grain Alliance are tailored to climatic conditions, precipitation levels and soil analysis results in each of the company's five clusters. This model allows the company to use resources efficiently and reach high productivity levels via monitoring of each particular field. Strictly following own policies and requirements toward crop rotation, selection of varieties, tillage and input procurement proves itself for the company resulting in high profitability levels.

In 2020, the holding moved to a new stage of precision farming adding modern precision planters to the machinery park. The basic priorities for the machinery are accurate sowing at a given depth and the speed of operations, which is of particular importance in spring when the soil in the areas of the company's operations quickly loses moisture. In addition to DT-equipped machinery, the holding's clusters use drones and satellite imagery in their production processes, mostly for crop mapping and monitoring. In order to obtain detailed data on the state of the soil and avoid losses due to drought or excessive precipitation, the company uses modern weather stations.

Collection of data from all the machinery, fields and clusters is a complicated process when it comes to data storage, synchronization and processing. All the data from the machinery and equipment used is transferred to the data-processing system provided by the same machinery supplier, which is a well-known international company. The system used to perform its tasks properly until recently, but the supplier has changed firmware and modified the interface, which made data analysis and systematization become more difficult. Noteworthy, data processing is performed solely by means of internal resources of the holding although earlier it used to outsource this function to local, Ukraine-based companies. "In the beginning, we worked on data processing with partner companies, but personnel changes on both sides have complicated the interaction. So, we started to work independently", comments the manager interviewed.

As the next step in digitizing agricultural production, Grain Alliance plans to test the precise application of fertilizers. However, currently, there is a lack of own competences inside of the company, especially with regard to the preparation of task maps needed for targeted fertilizer application. "In some cases, it is

impossible to integrate the software, and in others there is a lack of people who could build and support this process in terms of analysis and interpretation of the results", explains a manager.

In the view of own rapid growth and development of operational processes, Grain Alliance's management has decided to use a tailored-made software for management purposes. The in-house enterprise resource management (ERP) system makes it possible to plan and control all operational processes using one integrated system. As a basis, the company is using the 1C Enterprise[1] accounting system, which has been customized to the specific needs of the company by own IT specialists. Now the said ERP system includes the economic, logistics and accounting data, and even the GIS elements with machinery tracks. Given that the majority of agricultural enterprises in Ukraine are using the original 1C Enterprise system, Grain Alliance was inspired by own case of a successful upgrade and customization of the system and considered the possibility of bringing own expertise to the market. However, the company has ultimately decided not to engage in this activity as it would require additional investments to scale up the expertise. "We wanted to offer this solution to the market but we faced the fact that each large agricultural company has its own logic and operational processes, and customization would require significant individual refinements", explains a manager.

In the sphere of land management, Grain Alliance has digitized all of its lands with the help of a contractor. All fields with their geospatial and physical characteristics as well as all land lease agreements with their legal, duration and financial conditions have been organized in a single online interface. Among other things, this helped the company's land department to identify some of the land use-related risks. "We completed a large project to take inventory of all land plots and lease agreements, thus organizing and digitizing our land and bringing everything into a single online interface. Now all the fields are digitized, and every year we carry out additional digitization to update the information. The use of specific ultramodern software for cadastral purposes is less important, while the key to successful land management is its general logic", reports a manager. Cadastral data and information on leased and owned land plots are elements of classified information in the company. These data are used only internally and are not shared with external parties. According to the data of the public registers of land and property, Grain Alliance administers over 4000 land lease contracts (State Land Cadaster, 2023; State Property Register, 2023).

Thus, overall, the case of Grain Alliance suggests that complex joint projects regarding data processing and DTs implementation require excessive effort and cross-divisional personnel engagement. As data is often associated with confidentiality and its efficient use rests upon company-specific economic conditions, communication with contractors may become complicated and put a wider use of DTs on hold. This makes a company focus on the development of local arrangements that mainly aim to meet the company's own ongoing needs and, thus, a closed institutional infrastructure is the priority for a certain period of the company's history.

■ *DTs, shared and open institutional infrastructures*

Grain Alliance is committed to dedicating its expertise and resources to help deliver innovative and sustainable solutions to address some of Ukraine's most pressing challenges. The main objectives of these activities are to promote the development of local communities and improve their welfare. The holding supports educational institutions and contributes to the modernization of educational processes by supplying computers, multimedia equipment and other required technological components. In total, about USD 20 000 was invested by the company in this sort of support in 2022 (Rozvitok sela, 2023). As regards the achievement of sustainability or ESG (environment, sustainability, governance) goals, Grain Alliance is considering to adopt the concept of carbon farming, but has not made DTs a part of this process so far.

[1] The 1C Enterprise accounting system has been developed by Russia-based developers. According to the interviewed manager, many Ukrainian enterprises currently refuse to work with Russian software and are switching to other solutions. However, for Grain Alliance, the replacement might cause massive complications as the system is interwoven with all the operational processes. Thus, for now, the company keeps using 1C Enterprise.

3.2 Continental Farmers Group

■ *Company information*

Continental Farmers Group (CFG) is an agricultural company owned by the Saudi Arabia-based investment company SALIC, which operates in the west of Ukraine. It emerged in its current form in 2019, when two agricultural companies – Mriya Agroholding and Continental Farmers Group – merged and the newly registered holding company took the name of the latter (CFG, 2023a).

The merger was a complex process on all levels, including restructuring and redesigning of operational processes and corporate policies. Significant investments were allocated to update the machinery fleet of the holding, operational activities were optimized, and funding for the development of local communities in the areas of CFG's operations was preserved.

Currently, the product portfolio of the company includes crops and oilseeds, seed production and potato production and processing. As of 2022, the company consisted of 5 production clusters, managed 195 000 ha of agricultural land and employed about 2400 people (Latifundist.com, 2023b).

■ *DTs and closed institutional infrastructure*

Through different phases of its development, CFG has always been focused on improving production technologies, including those based on the use of DTs. This became the main driving force for building different types of infrastructure at the intersection of company's interests and various external factors.

The company managers report that ever since the introduction of DTs to the Ukrainian market, they were thinking about digitizing all the processes to collect data about every operation performed by the company. The process began with digitization of the sowing process, whereby 16 of the total of 30 planters owned by the company were re-equipped with the systems and solutions for precision sowing. This made it possible to control the seeding rate and the quality of seeds placement for each machinery section just at the time of sowing.

"[Successful reequipment] motivated us to look for similar solutions for other types of machinery and to gradually digitize all production and operational processes", says one of the linear managers of the holding.

A company-wide implementation of precision farming started with the introduction of autopilots and stirring systems. The machinery operators were initially hostile and unwilling to use the new equipment, as they were afraid of either losing their jobs or of additional workload associated with the new technology. However, as soon as they experienced the benefits, i.e. automation of processes, improvement of quality of operations, speed and better exploitation of machinery, they became more prone of accepting innovations. Currently, the operators want to work with machinery only if there is an autopilot installed because they realize the degree to which both performance and working conditions improve with technology. "Now an operator is a direct customer of the equipment, and each cluster of the holding has a person responsible for precision farming", confirms a linear manager of the respondent.

CFG uses DTs in combination with the information from satellites with high-resolution telescopes for field scouting and recording the quality of seedlings and condition of crops at different vegetation stages. These DTs include drones and various field analyzers with spectral cameras that can be installed on the machinery for recording during the field operations. Drones and satellite imagery is used for 100% of land cultivated by the company whereas field analyzers are applied in one of the company clusters so far. Currently, the holding is testing various-rate application of crop protection products by means of digital field analyzers and precise application of fertilizers.

Successful projects and quick returns from DTs in precision farming resulted in numerous synergetic projects at CFG. For instance, the agroholdings subcontracted a Ukraine-based DT company to analyze the tracks of planters, in particular the paths of the outer section of planters, to update the contours of the company's fields based on the fact of sowing with the accuracy of 20 cm. This way non-productive areas were identified and excluded to optimize operational costs.

In general, CFG prefers autonomy in the process of testing and application of DTs that improve their performance. When choosing whether to work independently or with a partner company in the field of precision agriculture, CFG first considers if it can implement technology using only internal resources. "We count man-hours, possible workload of internal projects, and other factors. If we find a counterparty ready to complete a project at an acceptable cost, we give it to contractors", confirms a linear manager. However, in some cases, support is needed to validate the adopted solutions. For example, the IT department of the holding closely cooperates with the Taras Shevchenko National University of Kyiv in order to improve the algorithms for big data processing.

In order to collect and process the data from numerous units of machinery of different brands, the staff used to work with different software and multiple accounts to synchronize (and not to lose) all the pieces of information. "Before we started using a single analytics platform, we had to work with the software of this entire "technological zoo", and look for ways to synchronize it all. This gave us the opportunity to better understand precision agriculture technologies, compare different solutions and choose the most suitable for our tasks", explains a manager. Accumulation of data on a single platform enabled the staff to collect the entire history of the field, scouting, machinery reports, crop photos, and drone videos. This approach makes all the data clear and accessible, providing solid grounds for decision-making.

Even though the software is smart and multifunctional, people still control and double-check the results. Therefore, CFG formed a special division responsible for data processing and management. The trained staff works with analytical platforms, prepares customized reports for different departments and controls the whole stock of digitized information. "We have formed a "flight control department" where all the data from fields are accumulated, and the controllers analyze where the equipment is, what it is doing at the moment, whether it is moving along the contours or maps, and what operation it is performing. In other words, they fully control the processes without actually going in the field", says a manager.

One more specific DT application area is the use of sensors, trackers and other similar devices to improve the efficiency of input use and logistics. The need for these monitoring technologies arises primarily from the necessity to fight and preclude theft during the use of every stock unit, machinery and equipment. "We began with installing fuel sensors, then we installed reverse sensors, and later we tried to connect to a Controller Area Network bus on the tractor. […] and eventually we connected all the machinery to a single [brand of the system] system and equipped it with GPS trackers", says a linear manager of CFG.

Despite the complexity of the structure and diverse regional distribution of clusters, the operational processes in the holding are unified, providing a possibility to compare and evaluate operational results across the entire company. Noteworthy, presence of such a unified platform provides a basis for a broader stakeholder engagement of the company using DTs.

■ *DTs, shared and open institutional infrastructures*

Since CFG is actively engaged in various community development projects as part of its corporate social responsibility (CSR) policies, it uses DTs also for cooperation with stakeholders in the areas of own operations. Recently, CFG has launched a project aiming to respond to a growing problem of bee poisoning from agrochemicals. In particular, the company is using the data from its unified platform to automatically send a notification of scheduled applications of crop protection products to beekeepers via a special app. In

addition, the app contains a beekeeper's map developed by CFG so that each of 600 registered beekeepers (Agrotimes, 2023) can observe the crops growing in the fields nearby, the locations where beehives can be placed, as well as the competing neighbors. For the company, this is an opportunity to understand how many beekeepers there are in the area, provide them with the necessary transport or commodities, build hives, and provide other required support. At the same time, beekeepers receive valuable resources and information to support their business as well as ensure future growth. The company plans to cover all 90,000 hectares of its land under honey-bearing plants with the app in the nearest future.

Another example of such shared infrastructure projects is exchange of the data collected by CFG through drone and satellite field monitoring with a precision farming company, which uses these data for crop mapping and geospatial planning and advises CFG based on the results of analysis. Having processed the information from CFG's monitoring technologies, the partner company may use it to provide agrotechnological advice to other clients, including medium-size farmers (i.e. agroholdings' competitors on the farmland market), researchers and public agencies. This particular co-creation has already transformed into an open partnership project, called The Continent of Innovations, aiming to bring the agricultural community together for cooperation on agrotechnological issues. In the framework of this project, CFG willingly and openly shares its best practices and experiences based on cooperation with various DT and service providers, discusses agricultural innovations and enhances expertise in agricultural production together with other farmers and input suppliers. The agricultural community regularly uses this platform to share experiences, publications, advice, and case studies by leading industry specialists.

The long-term strategy of CFG is built to conform to ESG principles and is embedded in its Code of Corporate Ethics and Business Conduct. Here, the company also implements DTs to the extent possible. A good example is the development of a Corporate Social Responsibility Map (CFG, 2023b), a special tool that provides an opportunity to view online the social investments of the company on a regional, district or village level as well as to obtain the contact information of local managers for support requests.

3.3 Astarta

- *Company information*

Astarta Holding PLC is a vertically integrated holding, which was founded in 1993 by Viktor Ivanchyk. Initially, the enterprise focused only on sugar production. It started agricultural production in 1997 and, since then, it has established a number of agricultural enterprises as well as acquired a number of sugar plants in several regions of Ukraine. Rapid growth and outstanding performance eventually resulted in Astarta Holding's shares being listed on the Warsaw Stock Exchange in 2006.

In 2008, the company was the first one in Ukraine to join the UN Global Compact Network. In addition, it was among the first to sign an agreement on the sale of carbon credits with the Multilateral Fund for Carbon Credits created by the European Bank for Reconstruction and Development and the European Investment Bank within the framework of the Kyoto Protocol (Astarta, 2023b).

Further development of the company included a large-scale investment program for the construction of storage infrastructure. As a result, Astarta became one of the market leaders in production, processing and storage of grain and oilseed crops in Ukraine with a total storage capacity of more than 560 000 tons. In 2021, Astarta completed the construction of an advanced soybean processing plant with a total capacity of 100 000 tons of soybean protein concentrate.

According to the company's annual report, it managed 220 000 ha of agricultural land and generated a net profit of EUR 65 million in 2022. Its total number of employees exceeded 6500 (Astarta, 2023a).

■ *DTs and closed institutional infrastructure*

Astarta started to actively implement DTs in 2016–2017 by investing $6 million in the purchase of new sowing machinery together with heavy tractors. The entire stock of agricultural machinery was equipped with the fuel level sensors and GPS equipment to allow for scaling of precision farming and increasing production efficiency throughout all regional divisions of the company. The holding also began to use starter fertilizers as an element of precision agriculture and launched 13 weather stations to discover the correlation between weather conditions and the agrochemical structure of soils.

In order to track the use of inputs, the holding implemented QR codes and GPS trackers for each stock unit. Now the managers are able to track the movement and use of each inventory unit and analyze the obtained information. The latter is especially useful for Astarta's soil science laboratory, which gains access to information about the selected samples in an online mode. For each individual sample, the system generates a QR code that contains all the information about the farming unit, the field and its specific sector. Codes are read by ordinary tablets, and the data is immediately pulled into the general report, which can be accessed by the managers.[2]

Implementation of the abovementioned technologies formed an internal request for the creation of a unified IT platform that would enable integrated management of agricultural operations and accounting. In order to develop such an integrated digital agribusiness management software, Astarta established an in-house IT company AgriChain in 2017.

Initially, the AgriChain platform was a custom-made software, tailored to the specific operational processes, logic and tasks of Astarta. It offered 2 separate basic products: a solution for managing an agricultural enterprise and a land management system. Over the first 2 years, the platform has developed according to the needs of Astarta's divisions and included new features, such as field monitoring, automation of business processes, task management, warehouse accounting, etc. Eventually, it transformed into a unified IT platform for agribusiness management that provides various sorts of real-time technological and planning assistance not only to Astarta but also to its supply chain partners. In 2020, the AgriChain platform was introduced to the Ukrainian market.

■ *DTs, shared and open institutional infrastructures*

The AgriChain platform is suitable for the needs of agricultural producers of various sizes. "With our solutions, medium-sized agricultural producers (of up to 40 000 hectares) optimize and manage operational processes, improve control over production processes and use of inputs, such as crop protection products, fertilizers and seeds, which both ensures transparency of the processes and improves the operational efficiency", says a manager.

As an experienced market player, Astarta is willing to share its expertise with private individuals and small businesses. The vision of the Astarta owner is that the holding can boost own efficiency only if the whole sector is efficient. As part of Astarta, AgriChain puts this vision into action by sharing the company's experience and solutions in the sphere of digitalization. "We had a case with a small agricultural company that had such a risky land [in terms of uncertain land lease agreements] that it could have lost it. By means of our app, they have digitized their lands, conducted an audit, inventory of contracts and so on, and eventually managed to minimize the risks of land use and stopped losing their land plots", comments a manager.

[2] Noteworthy, Astarta's soil science laboratory provides services not only to Astarta, but also to other agricultural enterprises, according to the interviewees.

The implementation of a land management system is beneficial not only to Astarta or AgriChain clients but also to their smallholder land lessors. The land management system reduces transaction costs and improves the efficiency of management of land lease agreements, as the needs for unnecessary meetings, document exchange and communication diminish. As a long-term result, rural communities also benefit from implementation of land management software: reduced transaction costs enable land lessees, such as Astarta or AgriChain clients, to pay higher land rentals to landowners. Accordingly, landowners can pay higher taxes and thereby improve the budgets of local communities. This is particularly important in the view of outdated physical and social infrastructure in rural communities of Ukraine.

In addition, at the holding level, Astarta is using digital tools for individual interaction with landowners. "Smallholder rural landowners – our land lessors – want to be our partners and they are a part of our ecosystem. We would not be able to work without them. In order to consider their needs more carefully, we have developed a chatbot that processes their requests and helps to receive various pieces of information, for example, a proof of income or proof of land rental payment from us to present it to tax authorities or similar", explain the managers.

The managers of AgriChain are aware that, in order to achieve best possible synergies and efficiency improvements, a software platform should be flexible and easily adjusted, and the producer willing to implement it has to be open-minded and ready for change of own business model. However, even in this case, an individual approach matters as the developers are willing to sell a customized project, not a software product. "We try to only work with companies that are ready for change, look deeper into their processes and offer tailor-made solutions for their needs. We implement these solutions by working in joint project groups", explains a product manager.

Working with shared infrastructures requires preservation and protection of data. Even though AgriChain is an in-house developer of Astarta and can be considered the agroholding's "digital wing", Astarta itself does not have access to the customer data of the AgriChain platforms. Moreover, many of the holding's competitors on the farmland market are using the AgriCahin application. "Almost all Astarta's competitors, namely 7 out of 8, are either partners or clients of AgriChain. Astarta has no problem with this and there is a contractual agreement that AgriChain does not grant Astarta access to the data of its clients", comments a manager.

Currently, Astarta is using its DT expertise to develop shared institutional infrastructures that go beyond the interactions that benefit local communities and offer solutions also for the development of the country's economy as a whole. For example, in 2022, Astarta completed testing of the electronic management system of transport consignment notes. The development of the system was led by the Ministry of Infrastructure of Ukraine to simplify and speed up logistics by replacing paper transport consignment notes with electronic ones to ensure freight transparency (Astarta, 2023a). This way the solution developed by a single market player evolved into an approach beneficial for the whole industry.

Furthermore, in the area of education, Astarta has launched IT Education in Rural Areas, the project that aims to improve computer literacy among rural population and provides IT trainings to children and adults in rural areas. The agenda for children includes visual programming in Scratch, designed at the Massachusetts Institute of Technology, and Robotics.

Another important direction of DT-based projects is environment protection. In 2020, Astarta in cooperation with the non-governmental organization International Environmental Security started an online project Eco-education in Communities aimed at promoting environmental awareness among the youth. In addition, the company introduced and implemented the resource and energy efficiency program Best Available Techniques at its sugar plants to achieve energy efficiency goals. The company's farming enterprises have already witnessed a reduction of energy consumption due to the use of modern agricultural machinery and innovative IT tools for agricultural management. For instance, energy consumption in the agricultural

segment reduced by 16% to 871kGJ representing a 26% share in total energy consumption of the holding (Astarta, 2023a). As a part of the Green Economy concept and focusing on sustainable development, Astarta implemented a system for accounting and calculating emissions of greenhouse gases and other contaminants under the requirements of the GHG Protocol and national legislation. The system involves the use of DTs as part of monitoring, analysis and detection procedures.

4. Discussion and conclusions

The present paper demonstrates how implementation of digital technologies by firms contributes to market development and improvement of the institutional environment in the agriculture of one of the Eastern European countries, Ukraine. The said improvements occur at different levels, including internal firm operations and interactions with immediate exchange partners, interactions with a broader set of actors, e.g., at the communal level, as well as the institutional environment as a whole.

The findings generally support the argument that complex technology enables coordination of activities not only within but also outside firm boundaries. Furthermore, two of the three studied agroholdings have been found to actively establish DT-enabled institutional infrastructures that not only pursue efficiency improvements for own benefit but also transform existing institutional settings.

More specifically, we find that, first, DTs assist the studied agroholdings in engaging with key stakeholders within *closed* institutional infrastructures that mainly benefit the agroholdings' own needs on the one hand. For example, all of the studied agroholdings are using cloud software, data from satellite and drone monitoring as well as AI-based analytics for administering thousands of land lease agreements with smallholder landowners. On the other hand, such activities add positively to existing institutional infrastructures characterized, for instance, by still incomplete public cadastral systems in Ukraine. Reduction of transaction costs associated with interactions with numerous landowners transforms into higher landowners' incomes and, respectively, generates more tax revenues that can be spent on infrastructure improvements in rural areas.

Second, the agroholdings under scrutiny have been shown to launch DT-based initiatives that bring about benefits to the participants who *share* access to them as well as to a broader set of participants. The Astarta agroholding has set up the e-platform called AgriChain, which provides agrotechnological, cadastral and procurement advice not only to its subsidiaries or the farmers that supply its storage and processing facilities but also to Astarta's competitors (based on fees). It seems safe to conclude that, by selling its product to the competitors, Astarta strengthens them, as in addition to having more expertise and experience of working in their local climatic and natural conditions, these competitors obtain a customized digital solution that improves their efficiency.

Another agroholding, CFG, cooperates with a precision farming company that processes CFG's data and, upon an established agreement, may share these data also with CFG's competitors. On the one hand, the adoption of such platforms aims to obviate the problem of underdeveloped public and private extension networks in Ukraine (Korinets and Yaroshko, 2023) and thus to improve supplier compliance with quality requirements. On the other hand, the use of own DT expertise to build the market for customized digital solutions (Grain Alliance and Astarta), indirect data sharing with competing enterprises (Astarta and CFG) as well as voluntary abstention from the potential (mis)use of its competitors' information (Astarta), suggest that firms may initiate an even broader transformation process. The latter would involve not only the establishment of a new market for DTs, but also the development of the institutional foundations for this market that can also spread to other markets and sectors. In our study, these foundations are exemplified by trust-based exchange relationships among market participants and, in the context of agriculture, promotion of good agricultural practices and biodiversity.

To this effect, our study shows that DTs help firms to take on an even more active role by serving as a bridging organization or institutional intermediary (Gatignon and Capron, 2023), thus substituting for public and nonprofit actors in establishing *open* institutional infrastructures. In this role, firms may foster and engage in cross-sector cooperation that benefits and empowers a broader set of actors. Particularly with regard to our study, some of the DT-enabled infrastructures developed by the studied agroholdings reduce institutional costs not only for these agroholdings alone but also, and primarily, for other actors. The launch of the application for beekeepers and of the CSR map by CFG are good examples of such infrastructures.

Interestingly, the choice of the governance mode for DT-enabled infrastructures may differ among agroholdings even with regard to the same institutional problem faced. For instance, in the view of poor agrotechnological extension services, agroholdings in Ukraine are generally interested in sharing their experiences of using precision farming technologies and modern DTs with other market participants. The willingness to share such sensitive information, in particular with neighboring (and thus competing) farms, has been initially driven by an instrumental motive to effectively prevent the spread of pests and diseases from the fields of the neighbors (Shmorhun, 2019). However, in the process of exchange, additional advantages in the form of new knowledge of production approaches have arisen also for the agroholdings initiating such exchange. One of the agroholdings studied in this paper, CFG, has recognized the benefits of knowledge sharing for the sector at large and initiated a freely accessible platform for agrotechnological exchange. Another agroholding under scrutiny, Astarta, has been found to engage in sharing its agrotechnological expertise on a commercial basis via its subsidiary, AgriChain. Yet, the other agroholding, Grain Alliance, wanted to apply an approach similar to Astarta but did not succeed due to resource limitations. Overall, our findings suggest that all three agroholdings largely recognize the institution-building and market development potential of DTs. However, the choice of the governance mode as well as the outcomes of the efforts the agroholdings make to encapsulate this potential have been found to differ.

The reasons behind the differing choices with regard to governance modes for exchange relationships catalyzed by DT implementation may depend on the organizational and managerial characteristics of the firm. The example of Astarta suggests an important role of leadership in a firm's engagement in the processes of institution-building, such as the development of an electronic transport consignment system in close cooperation with public authorities. Based on the results of our study, one can also assume that agroholdings like Astarta may be less concerned about sensitivity of engaging in data sharing initiatives due to a relatively low level of ownership concentration (as compared to the other studied agroholdings). A substantial portion of Astarta's share capital is being in a free float on an international stock market. In this context, recent studies have pointed to a positive effect of international listings on corporate transparency and disclosure of agroholdings from transition countries (Gagalyuk, 2017; Gagalyuk *et al*., 2021). On the other hand, as an internationally listed company, Astarta is particularly concerned with the interests of its shareholders and has to consider possible risks and be profit-orientated. These factors may have contributed to the choice of a commercial, contract-based knowledge dissemination approach involving the establishment of a separate legal entity (AgriChain). Altogether these examples of Astarta's activities point to the choice of a *shared* mode of governance of DT-enabled institutional infrastructures.

As regards relatively more ownership-concentrated agroholdings, in particular CFG, our findings demonstrate that, in addition to rather formalized shared arrangements, they rely on relational norms in governing sectoral and cross-sectoral exchange with respect to digital technologies. Previous research suggests that relational capital is the characteristic of an *open* institutional infrastructure that involves a polycentric governance model (Gatignon and Capron, 2023). One reason behind this choice may be the fact that CFG is, e.g., less spatially dispersed than Astarta, which makes it be strongly socially embedded in the regions or communities of its operations. This embeddedness may, in turn, cause the choice of a more inclusive governance approach.

The case of Grain Alliance, that has decided to use own DT-based solutions internally for the moment, suggests that the firm may lean toward the choice of a *closed* institutional infrastructure if it is for some

reason susceptible to institutional turbulence (Gagalyuk and Valentinov, 2019). As our study shows, Grain Alliance has faced lack of qualified personnel on the part of its partners that made it difficult to scale-up own digital infrastructure and expertise. Moreover, the agroholding has found itself in a lock-in situation when the potential exchange partners would supposedly be reluctant to using the proposed technology (of Russian origin) because of moral considerations (caused by the Russian invasion of Ukraine).

4.1 Research limitations, future research and impact of war

We realize that this study has limitations, as it is based on three case studies in one country involving a small number of in-depth interviews with the representatives of the studied firms only. This may raise questions regarding generalizability of our conclusions. However, we believe that at least some aspects should be applicable beyond the empirical context of the present research. In particular, there is evidence of rapid development of large-scale agroholdings in many countries, particularly in transition and emerging market economies characterized by weak institutional environments (Gagalyuk *et al*., 2021b). These agroholdings are using digital technologies for production and other purposes at an increasing pace (Agrohub, 2019; Chaddad and Valentinov, 2017). Thus, it is conceivable that the DT-enabled infrastructures could be used by agroholdings in other transition and emerging countries to address voids in market-based institutions of those countries.

Furthermore, our study focused on both privately held and publicly listed agroholdings, implying that some of their practices could be applied in different types of companies. For instance, the experience of both the publicly listed Astarta and privately held CFG may be useful for the understanding of how digital technologies can be used beyond own production needs and help to engage with a broad range of intra- and cross-sectoral actors.

Nevertheless, future research is certainly needed to identify the other important factors that affect the scale-up, spillover and, ultimately, institutionalization potentials of DT-enabled infrastructures. Furthermore, our understanding of the viability of shared and open institutional infrastructures that the present paper brings to the forefront, will improve if future research gives a detailed account of the rules and rule enforcement mechanisms governing these infrastructures.

In the context of this study, the above steps have been rather impossible due to the ongoing Russian invasion of Ukraine. The interviews made in terms of the study had to be rescheduled or postponed many times due to frequent blackouts caused by the Russian missile attacks on civil infrastructure in Ukraine. During the interviews, our respondents told that their businesses have undergone substantial changes, also with regard to the aspects addressed in this study. For instance, there is an official requirement from the Ukrainian government to limit the use of agricultural drones. On the other hand, the demand for satellite monitoring is growing significantly. However, overall, Ukrainian agriculture faces severe problems because of the war.

First of all, almost all grain shipments through the Black Sea are uncertain due to blockades of Ukrainian ports and ships. This makes pressure on domestic storage infrastructure and commodity prices. Second, prices for absolutely all inputs, fuel, spare parts and seeds increased significantly whereas bank loans have become hardly accessible.

Despite these complications, our respondents have reported that, for instance, all available funds they planned for expenditure in terms of CSR programs were reallocated toward humanitarian needs. The agroholdings used their production bases temporarily as logistics centers for humanitarian aid. Tons of humanitarian aid from abroad passed through them. They handed over their products and purchased medical equipment for the Ukrainian Military Forces. The total support from the studied agroholdings amounted to USD 12.5 million in 2022.

Production capacities of agroholdings, especially those located near the border with Russia, suffered from military actions and occupation. For example, at the beginning of the war, a fragment of a shell caused damage to an elevator of Grain Alliance in Nizhyn, Chernihiv region of Ukraine, and about 5000 ha were mined or contaminated by shell fragments. Consequently, the company did not cultivate these lands. "Total direct damages of the holding excluding losses, lost profits, etc. amount to several million euros", says a manager.

Working under martial law and the constant changes of wartime caused changes in typical procedures and operational processes. "Since the beginning of the war, we clearly understood that it is necessary to have working mobile versions of all software solutions, or mobile applications, including those with an offline mode, in order to enable people to work with data and make decisions in various conditions", says a manager of Astarta.

The communication and approaches to working with customers, partners and suppliers also changed significantly. All the parties showed sincere interest and understanding of all the circumstances and were open to providing support, postponing payments, and taking actions to help each other survive. "We have a client who has all the lands located in the occupied part of the Kherson region. We support the company and provide the opportunity to use our software and work under current conditions", says a manager of Astarta.

CFG implemented a retraining program for internally displaced people. The educational project aims to create new employment and career opportunities for professionals who have lost their jobs due to the situation in the country and have been forced to leave their regions of residence. The project (titled Continental Restart) also provides an opportunity to apply and expand engineering and technical qualifications, gain practical skills in agricultural engineering, as well as employment in agriculture.

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