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Agriculture 4.0 in Hungary: The challenges of 4th Industrial Revolution in Hungarian agriculture within the frameworks of the Common Agricultural Policy

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The impacts of the 4th industrial revolution, which is considered a "general purpose technology", do not appear only in the manufacturing sector or in the increasingly ICT-intensive services sector. Agriculture, which is using manufactured inputs in more and more automatized factories, and which relies highly on technology in its basic activities, has also been going through remarkable changes recently. Precision farming (1), optimized usage of scarce inputs (2) and so attaining a more economy and ecology-friendly (sustainable) farming system (3) are all potential positive outcomes of the technological development of Industry 4.0 taking place in agriculture.

In connection with this topic, our main aim is to determine the position of Hungary in this field, and whether there are any obstacles in this process. Both in the theoretical and empirical research conducted, we focus on the agricultural workforce, whether it is ready to keep pace with developments or if Hungarian farmers may be facing difficulties. Finally, as an outlook we examine the European Union's Common Agricultural Policy and its future changes, if it is currently or close to handling this challenge?

Keywords: agriculture 4.0, precision agriculture, Hungarian agriculture, Digital Agricultural Strategy

1. Introduction

Over the last few decades, agriculture – and of course in a broader sense natural resource management – has been facing a wide range of difficulties, challenges that require solutions beyond just the recent industrialization of farming activities. Global climate change, the necessity of resilient national and regional food systems, and the guaranteeing (establishment) of sustainable livelihoods for small-hold farmers are all related to present tensions in agriculture.

Improving productivity, effectiveness, and the competitiveness of agricultural activities can all be keys to answering the challenges in such a demanding environment. Thus, meeting the requirements of recent challenges requires complex analysis to plan possible solutions. There are different ways of addressing the challenges. In the present study we turn our focus on one of the possibilities: provided by the technological background, and the necessary technological readiness to facilitate its impacts on the productivity of agricultural systems. There are of course other paths being followed all over the world based on the circumstances, investment, and other factors that determine the overall situation of a country's or region's agricultural background. Participating in the Internal Market of the European Union, Hungary is left with only a few possibilities to address the present challenges and among them the technological readiness of the agriculture seems to be important. In the following chapters we will introduce the competitiveness problems appearing on the Internal Market, and the impact of development and technological readiness in agriculture. Precision farming (1), optimized usage of scarce inputs (2) and so reaching a more economy and ecology-friendly (sustainable) farming system (3) are all the potential positive outcomes of the technological development of Industry 4.0 taking place in agriculture.

In connection with this topic, it is necessary to gain an overview of Hungary's position in this field, whether there are any obstacles in this process, and especially what they are. Thus, the aim of the present article is to reveal *where Hungary and its agricultural sector are in the process of the necessary creation and improvement of the conditions that will determine its future competitiveness, what the potential deficiencies are, and what kind of public answers are being formulated in the limited leeway allowed by EU-membership on these challenges.* Recognizing the deficiencies in certain points shows where relevant actors should put more emphasis and effort, be they EU-level determinants or arising from the domestic field, or be they public or private investment.

We contribute to the better description of the problems or deficiencies by our empirical research. In our – by far not representative but in the meantime telling – survey we were to identify the domestic failings and challenges where, if a proper and effective coordination of public and private efforts and resources were to happen, we know, positive results would be achieved.

1.1. The structure of the study

After the introduction of our topic, in the first part of the study, the technological impacts of the 4^{th} industrial revolution (4IR) on agriculture will be described based on a literature review. Then potential parallels between the development phases of agricultural technology and industry will be shown. At their point of intersection, precision agriculture as an intermediary solution between advanced technologies of Information and Communication Technologies (ICT) and farming, ranging from livestock industry to crop production, will be discussed.

Then comes a short insight into the present heritage and importance of the agricultural sector within the Hungarian economy. Addressing the challenges requires first that they be described. The present research is an attempt to contribute to this, so the empirical research focuses on Hungarian practice.

The summary of the necessary technological development and the needs/opinions of the farmers surveyed will be compared to the present EU-level and Hungarian actions and measures, so a compliance-check is performed. The study ends with conclusions, suggestions, and outlooks about future research that may contribute to the better targeting of the needs of the actors in Hungarian agriculture.

2. Recent challenges of agriculture, and the related agricultural and natural resource management issues

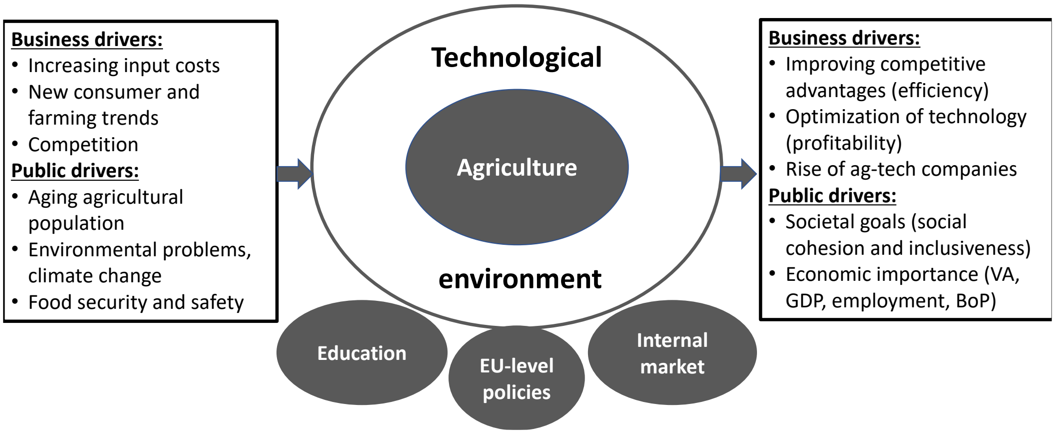
Beside acknowledging both simple and complicated problems, Turner et al. (2016) detail complex problems in agriculture, among which the frequently emphasized ones are the "usual" problems/challenges of agriculture of our times. They are also summarized in a recent report of the WGS (2018) as demographics, scarcity of natural resources, climate change, and food waste. Turner et al. (2016) characterize them as having tightly coupled components, dynamically changing behaviors, problems by which the efficiency of policies are regularly questioned, challenges where causality appears both in time and space, and where tradeoffs in the long-term and short-term interests and solutions appear. This complexity requires a different set of approaches and solutions, like the necessary interaction of actors, a systemic approach and response like agricultural intensification, improving farming systems, and increased and especially more effective resource or input integration and factor productivity.

Moreover, the original basis, the challenges, the possible solutions, and the outcomes vary country by country, by natural conditions, agricultural profile, the chosen agricultural policy, and the level of reliance on agriculture (Csáki and Jámbor 2012, Jámbor et al. 2016).

There are different ways of addressing the challenges. Among them, technological development in agriculture (the spread of automated, de-localized, and digitalized production and finally the commercialization of food) is just one direction. Other solutions can be Agroecology, which involves the application of ecological principles for the design and management of sustainable agroecosystem, so it is more in harmony with the Sustainable Development Goals (SDG) of the United Nations. Without doubting the validity of the last-mentioned solution, the present study focuses on the spread of advanced technology in farming. The spread of advanced technologies in agriculture should be considered as a possibility, rather than a constraint for actors in the market. Overall, the agricultural activities are put into a new environment, where different farming methods are/should be increasingly supported by advanced technologies (FAO 2017, WGS 2018), and where actors with different interests (business and public interests) have to react to the pushing and pulling forces appearing from different, public or private/business interests (Figure 1).

Pushing forces can be defined as pressures appearing on different levels of the market and in different orders of size or scale of operation. They can be both business or public driven pressures appearing on micro or macro levels. Meanwhile the other side of the Figure 1 summarizes those factors which appear rather as motivating (pulling) forces. These can also be a split according to their drivers – be they private or public – and according to their extent to or level at which they take place – at the micro or macro level.

Figure 1 Mapping the relevant challenges and environment of agriculture and the scales of intervention



Source: own construction

Huge differences have been mapped even between the so-called New Member States, which joined the EU in and after 2004. In their article, Jámbor et al. (2016) highlight that although original differences also occurred in agriculture after the transition to post-socialist countries, their decisions/policies in connection with agriculture had significant impacts even on their present production output, efficiency, and competitiveness. And at this point, we come to the fact that the primary sector of economies is no different from others that are traditionally considered knowledge-intensive sectors. Beyond the general comparative advantages appearing in labor and the capitalization of agriculture, the competitiveness of this sector also depends on other conditions like infrastructure, applied technology (FAO 2017) or favorable business environment, like in other fields of the economies. The development of technological background and innovative environment are also endogenous factors of growth, and finally, they appear in both national (Digital Agricultural Strategy of Hungary) and EU-level indicators (Digital Economy and Society Index, DESI of the EU) and policies. Thus, the aim of the present study is to identify the obstacles to future agricultural development and the improved competitiveness of Hungarian farmers. Furthermore, it is an attempt to collect potential solutions in addressing farmers' challenges in investing in such technologies.

3. New technological paradigm and its impacts in agriculture

The latest technological developments, the new productive assets and the appearance of a new technical and economic paradigm are all the manifestation of the so-called 4th industrial revolution (Manyika et al. 2013, Schwab 2016)[1].

Within this concept the latest technological changes are led by advanced digitalization (e.g. cyber-physical systems, cloud technology, or the Internet of Things, which contains location-based services), automation and robotization (e.g. near- autonomous machines and vehicles), 3D printing (i.e. tailor-made production becoming ever more feasible and profitable) and advanced bio- and nanotechnology (offering new materials and processes to regular industrial activities), and last but not least the use of intelligent data-based decision support systems (Pelle and Somosi 2018). The essence of these is a set of interconnected products, processes, and organizational, managerial, and business model innovations to bring fundamental changes in the entire economic system. Digital transformation in 4IR means far more than simply introducing new technological tools, machines, or solutions. Its huge value is the interconnectedness of appliances and the possibility of decision-making based on collected data and the ubiquitous computing and network infrastructure with self-configuring capability (Xu et al. 2018). These all contribute to the improvement of production in general and the transparency of processes, reveal potential malfunctions, optimize value creation and improve factor productivity (ElMaraghy et al. 2012, Xu et al. 2018). The technological environment of data collection, computing, and evaluation went through a remarkable development as well, including the potential to make data-based decisions (Babiceanu and Seker 2016). Intuitions and the experience of decision-makers are now coupled with facts and figures. The interconnectedness of things and data-based decision-making contribute to evolution and innovation in production in general.

In estimating the potential spread of advanced farming technologies, we have to mention the Digital Economy and Society Index[2] indicator, which is said to show the general digital preparedness of countries and their economic actors. In terms of overall DESI, Hungary is placed 23rd within the EU, but when the Integration of Digital Technology by Businesses is surveyed, the picture is different: Hungary obtains only 25th position, and if we see the Business digitization Index Hungary's position is even worse, only 27th in 2018[3]. From the perspective of Digital Intensity

[1] "Industrie 4.0" was initially introduced during the Hannover Fair in 2011. Moreover, it was officially announced in 2013 originally as a German strategic initiative to obtain a pioneering role in industries which are currently revolutionizing – at the time, only the manufacturing sector. Here the 4th refers to its rank in sequence of industrial periods from the second half of the 18th century until today, although we acknowledge that there are no clear-cut breaks between the phases of industrial development, especially in recent times.

[2] https://ec.europa.eu/digital-single-market/en/desi

[3] The Integration of digital technology indicator contains (a) 'business digitization' and (b) 'e-commerce'. From the perspective of the present study, the first is important, having five indicators (as % of firms using): electronic information sharing, Radio Frequency Identification (RFID), social media, eInvoices, and cloud solutions.

Index[4] (% of enterprises by level), in 2017 Hungary reached was 23rd. Altogether, if digital readiness is one pre-condition for the spread of advanced farming technologies, the results are far from promising.

The 4th industrial revolution is impacting the traditionally labor-intensive field of agriculture as well, furthermore, Xu et al. (2018) mention agriculture as a potential beneficiary of 4IR. The widespread use of 4IR technologies and solutions even in the primary sector underpins/confirms that they can be referred to as General Purpose Technology (GPT) (Dudley 2010). Spreading ICT usage in agriculture – similarly to other sectors – does not offer the final solutions in areas of the economy or life, but provides the tools to properly select and achieve new targets. As Bresnahan and Trajtenberg (1992, pp. 2) wrote: "as the GPT evolves and advances, it spreads throughout the economy, and in so doing it brings about and fosters generalized productivity gains."[5] Developed countries like the USA, Japan and some from Western Europe are trying to solve agricultural issues through mechanization, automation, and modernization. According to Sung (2018), the 4IR will serve as an opportunity both in time and environmentally to accelerate the spread of advanced farming technologies and thus increase the scale and overall commercialization of agriculture. Moreover, by the use of the Internet of Things (IoT), not only will farm production be able to improve, but due to time series data, the sum of earlier experiences and infrastructure, its value may even increase also.

3.1. Development stages of agricultural knowledge and technology

The first – longest in term and broadest in expansion – phase of agriculture lasted until the first third of the 20th century. It can be characterized by labor-intensive activity with a low level of productivity. It already applied some early inventions like the plough, and the mechanized agriculture also appeared, but its productivity was low[6]. A large number of small farms was common in a majority of countries (Jóri 2017).

The second phase of agricultural development started after the Second World War with several processes and research efforts made in this field. It is regularly referred to as *"the green revolution"*. Inputs of synthetic origin appeared. Nutrients, chemical fertilizers, pesticides, and even more effective machinery were implemented, so production capacity and effectiveness increased significantly

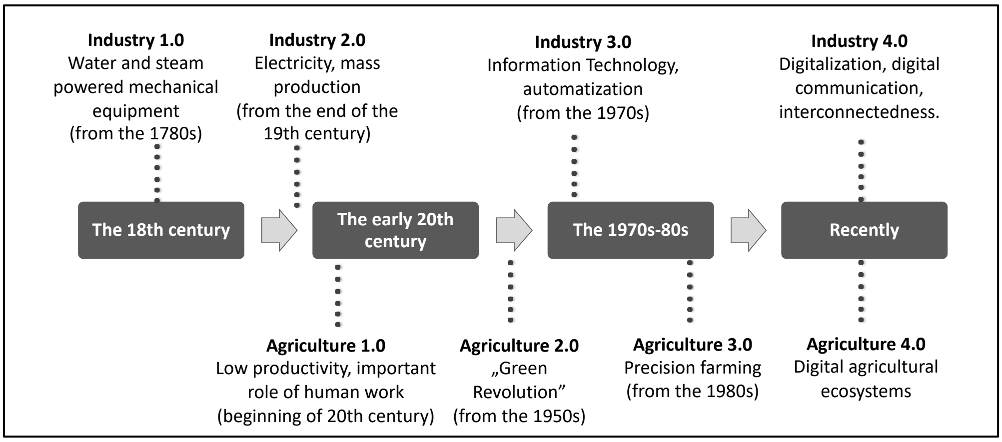
[4] The Digital Intensity Index (DII) measures the availability at firm level of 12 different digital technologies: internet for at least 50% of persons employed, recourse to ICT specialists; fast broadband (30 Mbps or above); mobile internet devices for at least 20% of persons employed; a website or homepage; a website with sophisticated functions; social media, sharing supply chain management data electronically; the use of Enterprise Resource Planning (ERP) software packages; the use of Customer Relationship Management (CRM); e-commerce web sales accounting for over 1% of total turnover, and business-to-consumer (B2C) web sales of over 10% of total web sales. The value for the index, therefore, ranges from 0 to 12.

[5] Bresnahan and Trajtenberg (1992) brought an even earlier example from agriculture. They cited Griliches's (1957) view on the method of inventing and breeding during the invention of hybrid corn seed as something close to their notion of general purpose technology.

[6] Representing this with a basic example: each farmer could produce enough food to feed about 26 people at this time (data from https://consulting.ey.com/digital-agriculture-helping-to-feed-a-growing-world/)

(Hesser 2006). Later, this period also brought genetic modification technology (GMO). In this development phase, the natural and engineering sciences went hand in hand with new management solutions – work organization, administration, control – to find applicable answers on the challenges of the time. Together, this all led to a significant increase in production – Bőgel (2018) refers to it as the "*period of the harvest*"[7] (Figure 2).

Figure 2 The development stages of industry and agriculture



Source: own construction based on Popp (2018)

In the following period, from the 1990s the impetus of inducing constantly increased productivity was deflected. Experts explain this by the law of diminishing returns. The applied inputs and farming solutions resulted in increased yields and productivity, but only up to a limit, and associated with increasing negative impacts on the environment. Thus, a special situation appeared, where developing countries were not even able to benefit from the earlier Green Revolution, meanwhile in the developed world new solutions were being planned to assist/support sustainable growth.

Digital transformation of agriculture seemed to be one possible direction, even if its spread and efficiency was not equal everywhere (Westerman et al. 2014). The appearance of digital technology as a General Purpose Technology in agriculture is witnessed from the late 80s. It brought the use of yield measuring right on machines equipped with Global Positioning System (GPS). This could even be considered as an early manifestation of decision-making based on data gathered by the help of Industry 4.0. The more precise yield maps supported the revelation/recognition of the spatial variation of yields and its natural and other causes. Modern/up-to-date and continuous yield measurement combined with GPS positioning was an important step towards computer-supported precision agriculture (Bőgel 2018).

[7] Development in this period resulted in each farmer being able to feed about 155 people.

This is why it is difficult to find an exact time when digitalized precision agriculture turned into the 4th phase of agricultural technological development. On Figure 2, Industry 4.0 and Agriculture 4.0 are positioned visibly at the same time. It should be emphasized here, that *Agriculture 4.0* or *Farming 4.0*[8], as the manifestation of impacts of the 4th industrial revolution is usually called, is not the same as the precision agriculture (PA), the one solution which is more and more based on the tools of ICT. In other words, Agriculture 4.0 is the application of digitalization processes and the evolution to Industry 4.0 within the primary sector and as such, it is more a technological environment. Meanwhile, PA, as will be introduced later, is a widely used farming method, which bridges or connects the two latest phases.

3.2. Advanced technologies and their application in agriculture

As Comparetti (2011) summarized, at the beginning of 1980s, precision agriculture, requiring GPS for sensing the position to which any measured field parameter must be geo-referenced, was implemented for the first time in the US. Mapping technology was introduced in Australia in the early 90s, and the first combine harvester mounting yield mapping technology was sold in 1997 in Europe. Since then, further improvements happened. In short, precision agriculture can be summarized as the right input, the right amount, at the right time and on the right spot.

The first wave of the precision agricultural revolution came in the form of satellite and aerial imagery, weather prediction, variable rate fertilizer application, and crop health indicators. Agriculture 3.0 was about the realization of gains deriving from early precision agriculture. The target of efficiency-based cost reductions was later replaced by profitability based on creative solutions, improved quality, or the development of new products (Jóri 2017). Meanwhile, the second wave of precision farming (that can be referred as the 4th wave of agriculture) – that is induced mostly by the earlier mentioned measures and solutions of 4IR – will aggregate the machine data for even more precise planting, topographical mapping, and soil data. So, since the new millennium, with the introduction of new technological advances, new machinery, and GPS tracking, each farmer will be able to feed about 265 people on the same unit of land by 2050.

With the use of Industry 4.0 technologies like artificial intelligence and the use of big data, and other methods, the potentials may increase further. The improved remote sensing and heading control (automatic steering), yield monitoring, diagnosis, measuring soil conditions, diagnosing harvest time, and monitoring crop health status, and the process of data originating from them are now also involved (Sung 2018). It contributes to more precise farming activities: instead of calibration of machines for

[8] Euractiv, 2016, Farming 4.0: The future of agriculture?, Available at https://www.euractiv.com/section/agriculture- food/infographic/farming-4-0-the-future-of-agriculture/
Euractiv, 2016, 'Farming 4.0' at the farm gates, Available at: https://www.euractiv.com/section/agriculture- food/opinion/farming-4-0-digital-technology-at-the-farm- gates/

one single but larger unit and instead of treating the whole livestock, it supports the adaptation to the spatially variable soil, water, and crop parameters within a field, and to the unique treatment of an animal (a specimen). Moreover, an additional important step is the real-timeliness of farming. Data collection and its processing happen immediately, data-based formulation of adequate decisions and delivering them are not separated by time from data collection. There are several machines, appliances, and applications that currently can communicate with each other, sometimes even without the need for human intervention (Bőgel 2018).

Nothing shows the expansion of this special market better than the numbers of sales of machines equipped with advanced and interconnected technologies. The increasing focus on farm-efficiency and productivity is expected to induce the growth of the agricultural robot market. Of the industries facing automation, agriculture could see the most benefit from robots over the next few years. And the farming robot wave, along with other new agricultural technology, could come even sooner, and with a bigger increase[9]. According to business data, the agricultural robot market is expected to grow from USD 2.75 billion in 2016 to USD 12.80 billion by 2022, at a Compound Annual Growth Rate (CAGR) of 20.71% between 2017 and 2022[10]. According to the GSA (2018), the CAGR of the global precision agriculture market will be around 12% through 2020, whilst the total market value will surpass USD 5.5 billion by then.

3.3. The benefits and potentials in precision agriculture based on Hungarian examples

Besides the subject of precision agriculture introduced earlier, its economic impact should also be emphasized. Its impacts can both be measured from profitability and from the return on investments (investment recovery) aspect. The present study focuses on researches made in Hungary since the empirical research presented later, which has also been delivered in this environment. Moreover, the focused studies presented on the potential impacts of introducing PA in arable crops production.

According to the study of the Hungarian Research Institute of Agricultural Economics (Kemény et al. 2017), the value of the overall economic impacts of transformation to PA was about 6.9% of 656 farmers/holdings reported. More precisely, *yield growth* (wheat: 7–17%, corn: 2–9%, sunflower: 6–10%) was detected (Kemény et al. 2017) together with the controlled and restrained environmental impacts also mentioned in the study by Hart and Bas-Defossez (2018).

When we come to *investment recovery*, the same research (Kemény et al. 2017) found that the investments targeting software and precision tools were recovered in farms both over and under 1000 hectares. But of course, differences were highlighted: in case of an exchange of complete machinery, smaller farms should face investment of over 500,000HUF (EUR 1,600) per hectare, meanwhile agricultural

[9] https://www.investors.com/news/farming-robot-agriculture-technology/
[10] Data from https://www.marketsandmarkets.com/Market-Reports/agricultural-robot-market-173601759.html

holdings extending over 1000 hectares have to invest around 328,000HUF (a little more than EUR 1,000) per hectare. Such investment would induce about a 6 (small farms) to 9% (holdings) increase in yearly incomes.

Another study by Lencsés (2013) also shows the differences between the potentials in investment recovery. It investigates the potentials by already differentiating by the size of the farms, their investments, and by the future prospects being them pessimistic, realistic, or optimistic. The results show that investments to introduce PA technologies are recovered only in case of medium and large agricultural holdings. These findings align with the results of Smuk et al (2009) which proved by modeling that the investment recoveries are highly dependent on, and show a strong correlation with, the size of the farm/agricultural holding. This is not a surprising result when considering that despite the advantages of Industry 4.0 for large enterprises, small and medium-sized enterprises (SMEs) often face complications in innovative processes due to the continuous development constraint in innovations and technologies (Zambon et al. 2019). This fact increases the complexity of the problem and the challenge that decision-makers face if they are willing to improve the innovative background of Hungarian agriculture in total, and not just of those bigger holdings that are already capable of improving.

4. Hungarian agriculture

As mentioned earlier, Member States (MSs) face different pressure (pushing) and challenges (pulling forces) but in the meantime, they also have limited means (lack of traditional own agricultural support system) to improve their positions. For Hungary, it would be an important task to improve especially the competitiveness of its agricultural sector. As Bojnec and Fertő (2008), Csáki and Jámbor (2013) revealed, after their accession to the EU in 2004, Hungarian farmers and the agricultural sector faced serious difficulties and remarkable reductions in the competitiveness of agricultural products both in price and quality, especially in the field of higher value-added, produced products. Altogether, there are several reasons which allowed ineffectiveness to pervade Hungarian agriculture of the present. Among other things, the following should be highlighted, since they are related to policy decisions:

(1) the traditional lack of networking and cooperation in agricultural activities (Juhász 2016),
(2) the wrong-headed agricultural policy that was not effective in exploiting the beneficial use of pre-accession aids coming from the SAPARD fund (Csáki and Jámbor 2013),
(3) the pre-accession policy targeting mostly the artificial creation of competitiveness through price and market support, that neglected measures for inducing agricultural competitiveness (Csáki and Jámbor 2012),
(4) the decision to implement the simplified Single Area Payment Scheme (SAPS) embodied in the Copenhagen Agreement in 2002

(5) and last but not least, during the first Multiannual Financial Framework Hungary contributed to as a member (the end of 2000–2006 and 2007–2013) we gave priority to direct agricultural support (60%) instead of support for rural development focused on the development of competitiveness and agricultural environment (Csáki and Jámbor 2012). Later in the present period of 2014–2020, this rate increased even further to 72%.

Besides these policy conditions, the decisions of farmers in their switch to producing higher value-added products is also determining their future. Here the technological background, professional knowledge, and the range of investment opportunities are all having remarkable impacts. With the above-mentioned unfavorable policy heritage, the changing technological environment and the *pushing and pulling drivers especially of businesses* should somehow be addressed in the near future. It would be necessary if Hungary wants to improve its position on the EU's internal market of agricultural products, and so, indirectly, conditions for Hungary's agricultural population - performance as *a driver of development*.

4.1. Hungarian agriculture's position in the economy

Besides the unquestionable importance of agriculture in food production, in producing basic raw materials for the secondary sector, and in its role in rural areas, its contribution to the whole economy can be also measured. Based on the indicators shown in *Table 1*, a balanced performance is visible.

Table 1 Basic indicators of Hungarian agriculture (as total contribution, year by year)

	2010	2011	2012	2013	2014	2015	2016	2017
Contribution to GDP (%)	3.0	3.9	3.8	3.9	4.0	3.7	3.7	3.3
Contribution to gross value added (%)	3.5	4.6	4.6	4.6	4.7	4.4	4.4	3.9
Employment (%)	4.6	4.9	5.0	4.7	4.6	4.8	5.0	5.0
Investments (%)	4.8	5.6	5.8	5.9	6.0	4.8	5	4.8
Trade balance (surplus) of agricultural products (billion HUF)	580	763	1007	992	900	889	806	915

Source: own construction based on the data of the Hungarian Central Statistical Office (2018–2019)

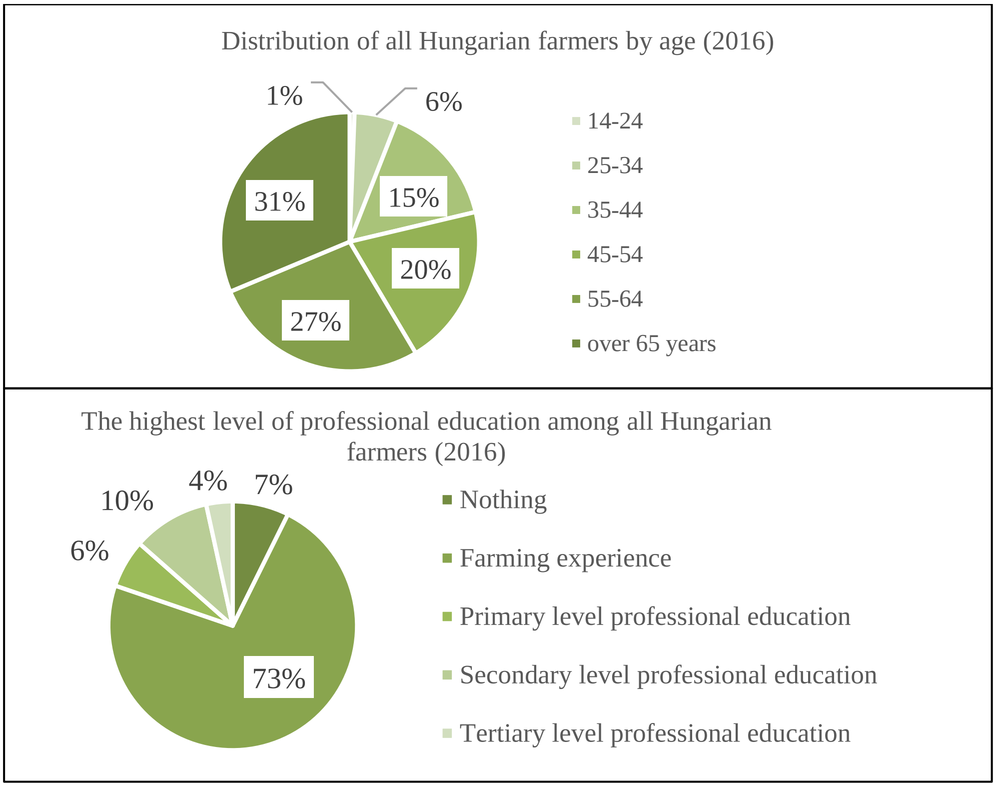
The contribution of Hungarian agriculture to GDP was 3.3% in 2017. The same indicator for the EU average was 1.2%. In agriculture's contribution to gross value-added, Hungary reached 3.3% (with only Romania, Bulgaria overtaking it in this field, and with Greece attaining the same rate), although meanwhile, the same indicator for the EU-28 was 1.3% in 2018[11].

Agricultural employment in Hungary is again over 5%, which is higher than the EU-average, but this could be a result of whitening the sector by new regulations

[11] Calculations based on Eurostat data using gross value added and income by A*10 industry breakdowns [nama_10_a10], while the definition of the agricultural industry is based on Division 01 of NACE Rev. 1.

providing easier, less complicated part-time and seasonal employment in agriculture. What is more important is the distribution of Hungarian farmers by age and by educational background (Figure 3). The Hungarian agricultural population coincides with the EU average as the majority of farmers are above 55 years. More problematic is their professional education. Compared to the rate of tertiary education graduates with respect to the total population of Hungary, which was around 18% in 2016.[12] tertiary level education is boasted by only 4% of the agricultural population. It could be a promising sign in connection with this indicator that, in the age group of 25–34 years, this rate is above 6%.

Figure 3 The distribution of Hungarian farmers by age and educational background



Source: own construction based on the data of the Hungarian Central Statistical Office (2018)

Furthermore, there is a remarkable difference in the educational background of farmers and managers of agricultural holdings. Due to a lack of recent data, only those from 2010 can be compared: 2.6% of the former group finished higher education, compared to the 44% of managers of agricultural holdings.

[12] Data is from the Hungarian Central Statistical Office.

4.2. Overall performance of Hungarian agriculture

The educational background, besides several other factors, has a huge impact on the productivity of agriculture. A complex indicator of this is the *total factor productivity (TFP)*, which according to the Eurostat shows the ratio between the change in production volumes over a given period and the corresponding change in inputs (or factors) used to produce them, and hence measures the growth in productivity over a given time span. It became a key indicator of the economic performance of agriculture and a driver of farm incomes and shows how efficiently the agricultural sector uses the resources that are available to turn inputs into outputs. A change – growth or decline – in TFP results predominantly from the change in public investments in infrastructure (irrigation, electricity, roads) and in agricultural research and development, from the changing efficiency in the use of water and plant nutrients, from the introduction of new technologies, managerial skills, etc. Although there is a general belief in the progress of technology in improving resource efficiency, the EC (2016) acknowledges that this is challenging in agriculture, as working with living organisms in outdoor conditions introduces variability and limits to growth.

Overall, between 2014 and 2016, the EU-28 experienced a 2.4% growth in TFP. In this period, post-2004 MSs (with an increase by 4.8%) narrowed the productivity gap and approached the higher TFP level of the pre-2004 MSs (which achieved a lower, 2.0% growth in TFP) of the EU. Besides the relative distance from the technology frontier, other drivers of this increase might be in many cases increasing labor productivity, but also improvements in yields (EC 2017). In the aforementioned period, Hungary achieved a 9.2% increase, meanwhile, the average annual change in TFP between 2006 and 2016 was a little bit over 1% (EC 2017). By these numbers, Hungary ranks among the low growers' group with Slovakia and the Czech Republic (EC 2016), but Baráth and Fertő (2016) also put Poland in this group. The Hungarian performance can be explained by the fact that per capita public expenditure on R&D in agriculture in 2014, the same as in 2005, was the second lowest for Hungary as member of the EU (EC 2016). It would, however, be essential to improve technological development in order to increase TFP. In the post-2004 MSs, it is important, because there is a lag behind developed MSs in technological development (Baráth and Fertő 2016).

According to the *Agriculture Performance Index* developed by Jámbor et al. (2016), Hungarian agriculture has been in the medium/average performers' group both by productivity and by efficiency sub-indicators in the examined period of 1999 to 2013. This research served as evidence to the earlier study of Csáki and Jámbor (2013), which claimed the comparison of MSs showed that those countries that made a switch to higher value-added agricultural activities (like dairy sector and fruit production) during their transition period, before their EU-accession, could later produce better performance.

Both the latest cited studies agree that Hungarian agriculture – to b more precise, its decision-makers – could not take the advantage of the opportunity to take advantage of the possibilities of the first decade of EU membership. Differences in the quantity and the quality of land/soil, in the labor force, and the capital background, all had a significant role in later differences in the agricultural performance of the countries. In Hungary, the capitalization of agriculture did not increase in the period between 1999 and 2013 (Jámbor et al. 2016). Regarding farm structure, the duality revealed was the insular presence of big, capitalized, more efficient farms surrounded by small, ineffective farms run by farmers usually of a low educational background. Furthermore, in contrast to the Czech and Polish examples, the quick implementation of privatization processes in the agri-business, resulting in significant foreign ownership of the food processing industry, to the detriment of local farmers in the early 1990s, also did not favor later agricultural development. Overall, the lack of transparent, comprehensive, and well-thought-out Hungarian agricultural policy resulted in the absence plans for the future (Potori et al. 2013, Jámbor et al. 2016) and the failure of readiness/preparedness for increased competition after accession (Csáki and Jámbor 2013).

5. Farming 4.0 in practice – an empirical research

At the beginning of 2019, we distributed a survey among Hungarian agricultural enterprises and farmers asking them about their situation, opportunities, and needs in connection with Industry 4.0 technologies. Our main questions on which the empirical research was based were as follows:

– What are the main motives/incentives of Hungarian farmers in using advanced technologies during their agricultural activities?
– Will such advanced technologies replace human interaction in the future of farming?
– What are the main obstacles and limits in the spread of technological development in Hungarian agriculture?
– What measures might support the technological development of Hungarian agriculture?

5.1. Research method and sample

Survey research using a predefined series of questions was used to collect information from farmers and managers of agricultural holdings. The questionnaire contained approximately 30 closed questions that ranged from the basic topic, like the form of their activity, their profile, and their size, to questions in connection with the research topic of the present article. With regard to the technologies used, motivations, suggested supports, etc. the respondents could mark more answers.

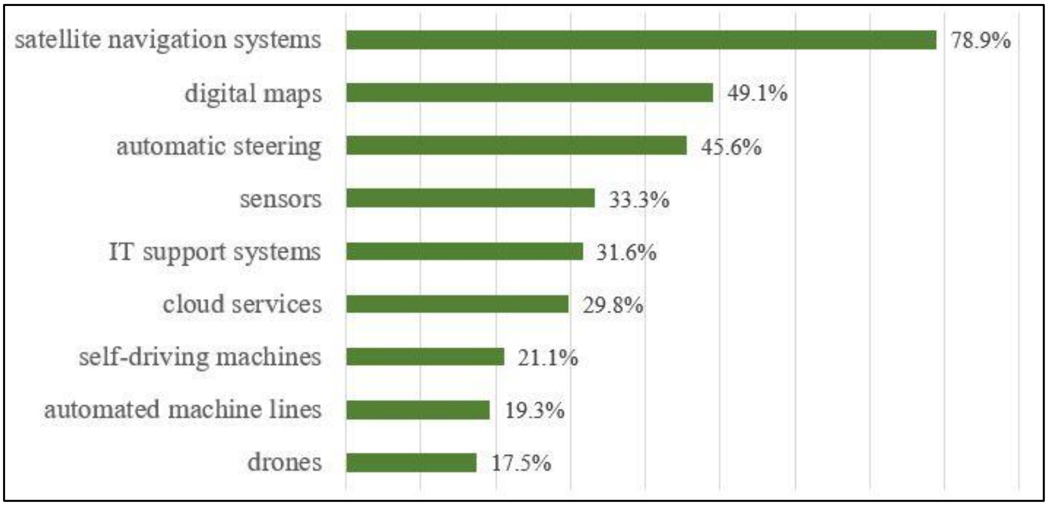
The questionnaire was sent to farmers, managers and other stakeholders primarily via the internet, social media groups, and e-mail through an advisory network of the Hungarian Chamber of Agriculture. Questionnaires were also filled out personally at professional events and agricultural forums. Altogether 134 questionnaires were filled out. During the analysis of the results, the limitations of the results became evident. The educational background of the respondents was not in accordance with what is described earlier in the present article about the Hungarian agricultural population. The distribution by age of the respondents is: 16.4% between 18–30, 23.9% between 31–40, 25.4% between 41-50, and compared to the total sample, only 34.3% were over 50 years. Altogether 81.3% (27.1 and 54.2%) of the farmers who apply advanced technologies in farming were in the below 40 years category. What is even further from the Hungarian reality – as presented in sub-chapter 3.1 – is that 78.4% of farmers in the survey had tertiary level professional education. So, *the results of the survey must be interpreted as messages containing urgent deliverables, since they come from the well-educated and younger agricultural generation of Hungary*.

5.2. Results of the research

More than half of the respondents, 56.7 percent said they did not apply the listed technologies (among others: satellite navigation systems, digital maps, automatic steering, sensors, cloud services, drones, etc.) in their business activities. The rest of the respondents, 42.4 percent, use at least one of the listed technologies in their business activities according to the distribution depicted in Figure 4.

Most of the advanced technology users implemented satellite navigation systems (78.9%), digital maps (49.1%), and automatic steering (45.6%). Approximately one-third of users applied sensors (33.3%), IT support systems (31.6%), and cloud services (29.8%), and nearly one-fifth of them used self-driving machines (21.1%), automated machine lines (19.3%), and 17.5% of them use drones.

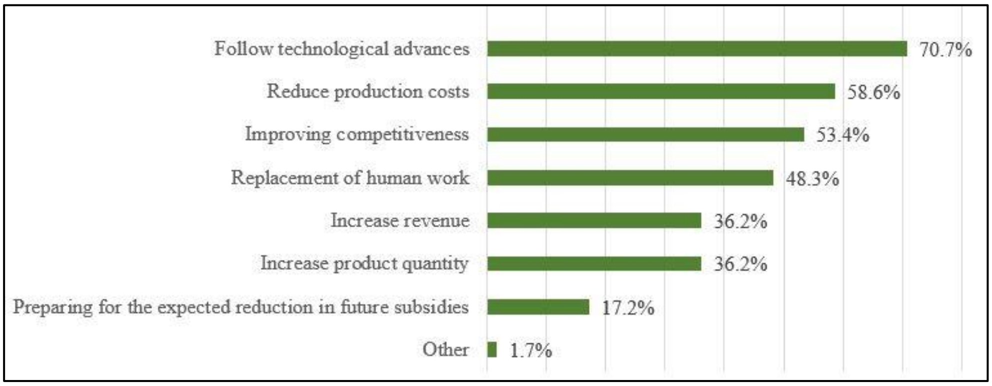
Figure 4 The distribution of applied advanced agricultural technologies



Source: Own construction based on the empirical research

One surprising result was in connection with the motivations in the implementation of advanced technology. Besides the “general” incentives of reducing the production costs (58.6%) and increase revenue (36.2%), the wish to follow the recent trends in technology was in first position (70.7%). The potential to improve micro-level competitiveness (53.4%) was also placed high among the motivations.

Figure 5 The motivations of actors using advanced technologies in agriculture



Source: Own construction based on the empirical research

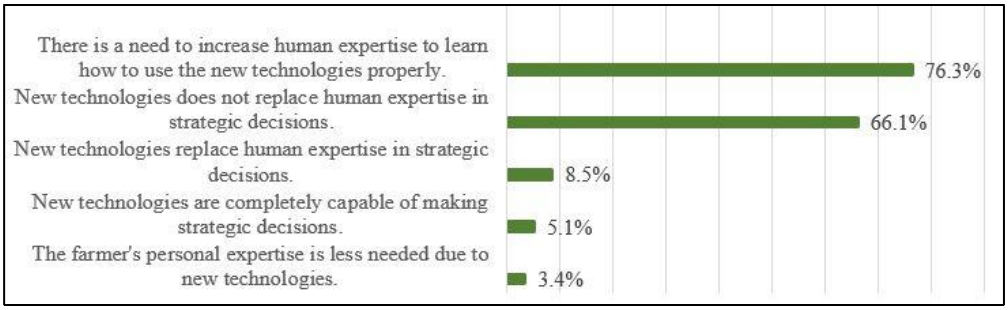
Although in sub-chapter 3.1 it was mentioned that agricultural employment increased slightly, here the intention to replace human labor (48.3%) is in line with the recent news about labor shortages in agriculture.[13] Given the aims of the present article, even the answer “preparing for the expected reduction in agricultural supports” reaching 17.2% is an important sign. In the subsequent discussion of the compliance of EU CAP with productivity and efficiency requirements, this will be further detailed.

In connection with the required knowledge in the use of advanced technologies the research brought the same results as other research about the impacts of technological advancements in other sectors (Szalavetz and Somosi 2019). Here the role of knowledge in farms using Industry 4.0 technologies has evolved and increased (Figure 6).

More than three-quarters of respondents said that there is a need to increase human expertise to learn how to use the new technologies properly (76.3%). More than two-thirds said that the use of new technologies does not replace human expertise in strategic decisions (66.1%). Therefore, the majority of responding agricultural enterprises and farms said that the role of human expertise has increased as a result of using new types of technologies, and not reduced, and only in a low proportion (8.5%), was the perception that new technologies replace human expertise, or the farmer’s personal expertise is less needed due to new technologies prevalent (3.4%).

[13] https://www.agrotrend.hu/hireink/a-mezogazdasag-a-hatalmas-munkaerohiany-erzekeny-terulete

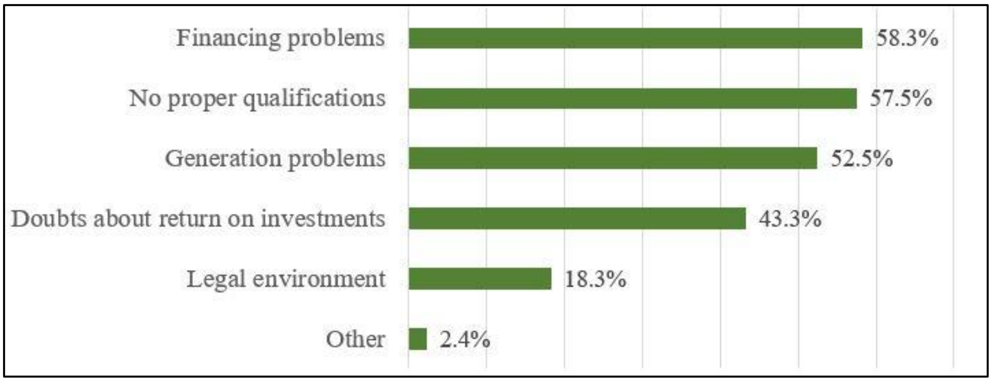
Figure 6 The role of human expertise in connection with advanced technologies



Source: Own construction based on the empirical research

Another focus of the research was the revelation of the potential obstacles of the spread of advanced technologies supporting agricultural activities in Hungary. As shown in Figure 7, financing problems (58.3%) were indicated as the first obstacle, followed closely by the lack of proper qualifications (57.5%) and generation problems (52.5%). Hence, the aging Hungarian agricultural population, which is further hampered by a lack of educational background (highlighted in sub-chapter 3.1), is visible on the micro-level after all. In addition to these three factors, there was a significant proportion of doubts about return on investment (43.3%). This is in line with the afore-mentioned studies by Smuk et al (2009), Lencsés (2013) and Kemény et al. (2017), which showed investment recoup depends on the size of farms and the rate of necessary investments, and may range only from 6-9% increase in the future incomes.

Figure 7 Obstacles to the spreading of Industry 4.0 technologies in agriculture

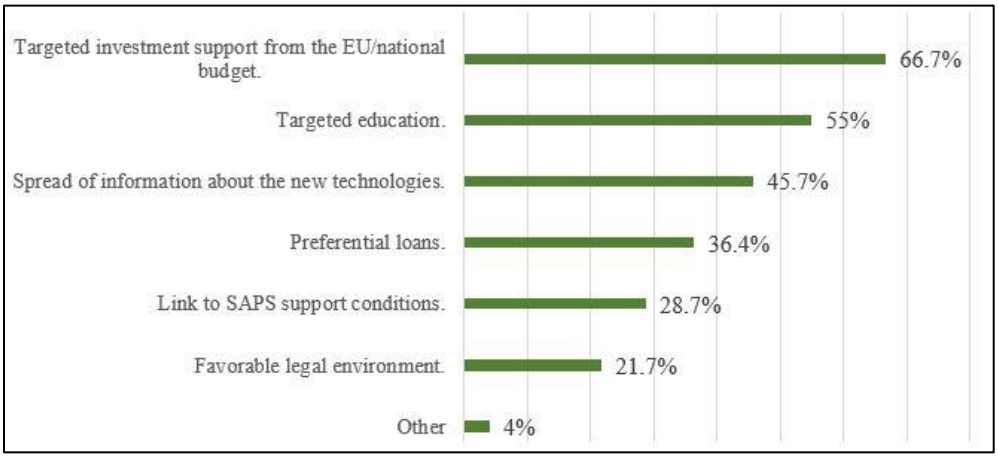


Source: Own construction based on the empirical research

According to nearly one-fifth of the respondents, the legal environment[14] may also be an obstacle to the spread of new technologies. Finally, 2.4% of respondents mentioned "other" obstacles, such as corporate culture, expensive data traffic, lack of online coverage, fragmented fields.

When the respondents arrived at naming the supporting factors of the spread of advanced technologies in agriculture (Figure 8), most of them indicated that targeted investment support from the EU/national budget (66.7%), targeted education (55%), spread of information about the new technologies (45.7%), and preferential loans (36.4%) would support its wider use. Linking SAPS support to investment in advanced technologies was mentioned by almost one-third (28.7%) of the respondents, but others especially highlighted that this would not be a favorable change in the SAPS system since it is already complicated enough to meet all its conditions. Mentioning the creation of a favorable legal environment is in accordance with the difficulties that derive from the aforementioned inadequate regulation.

Figure 8 Key factors in the spread of Industry 4.0 technologies in agriculture



Source: Own construction based on the empirical research

Here, the "Other" factors (4%) were responses such as: reducing costs, increasing purchase prices, and creating a professional, independent advisory network. Based on the answers and the deeper personal discussions three parties are likely to emerge: one would require professional assistance from the part of the authorities and the relevant ministries, the second would like to see an increase in financial support, and the last group would ideally like a combination of the two.

[14] According to the respondents' experiences from abroad, in general, it is a price increasing factor if data of soil, irrigation, and past and future potentials in yields are collected in a time series for a special unit of land. But recent Land Law regulations in Hungary – besides its other anti-market regulations – does not support the increase of value embodied in the price of land. Others mentioned the regulation of drones for agricultural purposes or water management regulations.

6. Compliance(?) of CAP and Hungarian measures with the necessary technological development

When one intends to map the potential factors of technological development in agriculture, the different levels and their impacts should all be analyzed. Governance issues, infrastructure, connectivity, data ownership, but also the emphasis on specific sectors like agriculture are – beside the increasing impact of international processes derived from the most opened markets ever – being shaped by the private sector, governments, national strategies, legal systems, but also by regulations of the EU and other international organizations as well (FAO 2017). For example, even the World Economic Forum is currently supporting agricultural transitions in 21 countries through its “New Vision for Agriculture” initiative[15].

The present study is not putting the analysis of the EU's CAP into main focus. Other studies (Gorton et al. 2009, Möllers et al. 2011, Popp and Jámbor 2015) have done that, even with an emphasis put on the impacts of the CAP on the agriculture of post-2004 MSs. Gorton et al. (2009) analyzed that the CAP is not suitable for this post-socialist region, and they even listed the reasons for that. Later Popp and Jámbor (2015) also found that the CAP was obviously hardly able to meet the challenges it faced before and during the present 2014-2020 period due to the inconsistencies between the predefined challenges and the measures proposed to meet them with respect to the territorial imbalances of the EU’s agricultural sector. The ongoing challenges in conjunction with new ones (technological readiness as a tool to be able to improve competitiveness) and the design of the forthcoming MFF also raise doubts in connection with its future success.

Just to highlight some private actors among the pushing forces of business drivers we can mention service providers, actors from manufacturing and supply, participants in the Agrifood industry, research institutes and innovators, and finally the policy creators. These actors are split by their scale of operations from the farm level, through regional, national, European levels all the way to the global level (GSA 2018). Increasing input prices as a pressure on farmers are transmitted by these agricultural input suppliers. Among the incentives of business drivers to keep pace with the innovative core of agriculture, one could cite the increasing number of Ag-Tech companies providing farm management solutions and applications.

Without aiming to give an exhaustive analysis, only a few stakeholders influencing the basic factors of agricultural improvements/development through their regulatory and financing potential will be mentioned, with respect to the results of the empirical research.

6.1. Compliance of CAP with the present technological environment

Among the challenges of adopting Farming 4.0 technologies from the perspective of the farmers, we can mention the necessity of common standards (1), the ability of

[15] http://theconversation.com/the-battle-for-the-future-of-farming-what-you-need-to-know-106805

farmers to modernize (2) and the modernization of infrastructures (3) (EC 2017b). The EU and its policies have something to do with all three areas. Here the focus is put on the ability of farmers to modernize.

After the latest CAP-reform concluded in 2013, the Commission initiated an action to collect ideas on the "modernization and simplification" of the CAP. A communication was published in 2017 titled "The Future of Food and Farming", which outlined the Commissions ideas for further CAP reform to coincide with the introduction of the next multi-annual financial framework (MFF) of the EU for the period 2021–2027. The objectives of the Common Agricultural Policy for the upcoming period are:

- ensuring fair income for the actors in the sector (1);
- improving competitiveness, including by prioritizing the development of research, technology and digitalization (2);
- improving the position of farmers in the food chain (3);
- action against climate change (4);
- supporting efficient management of natural resources (5);
- preserving biodiversity (6);
- generational renewal support (7);
- developing rural areas (8); and
- promoting sustainable production of safe, nutritious food (9).

As is widely known, the CAP as % of the MFF will receive 28.5% compared to the present period's 35.3% portion (Matthews 2018). In respect to this, it should be mentioned that the role of subsidies in the future of farmers could be ambiguous. As Pechrová (2015, 16) wrote based on the Czech example, direct subsidies "can improve farms' viability, but may mitigate farmers' motivation to engage in efficient resource usage." If the criticism, that CAP preserves conditions of ineffective farming are valid, such a cut in support may contribute to the necessary endogenous improvement of productivity implemented by the farms themselves. The use of advanced technology may later supplement the lower direct financial support.

In addition, about 10 billion EUR will also be available in the Horizon Europe research program during the next MFF, although not as a direct income substitution. This will support research and innovation activities in agriculture, food, and rural development. The agricultural **European Innovation Partnership (EIP-AGRI)** combines the resources of Horizon Europe and Rural Development to contribute to the digitization of agricultural holdings in rural areas, including the spread of precision farming techniques, and thus to contribute to sustainable and competitive agriculture (EC 2018). It aims to foster competitive and sustainable farming and forestry that *"achieves more and better from less"*.

Beyond financial support, it is also essential to build a stronger innovative network as well. There are several initiatives, like the **Agricultural Knowledge and Innovation Systems (AKIS)** with which the EU aims to boost initiation and development of innovation projects, to disseminate their results as best practices to support their use as widely as possible.

Overall it is visible that the new EU agricultural policy aims to strengthen actors' capacities for innovation by taking into account the complexity (as mentioned also in the introduction part) of innovation processes. Faure et al. (2019) summarized the key innovation support services (ISS) that help actors in agriculture-related innovation. Even in this specified case, their results show that ISS depends on the phase of innovation. During the initial phases – where the majority of Hungarian farmers are –, there is a need for innovative support services (e.g. network building, financial and other support for the innovator). In the latter phases – where some best performer, Hungarian insular agricultural holdings are –, there is a need for more conventional services (e.g. training, further credit for constant development). Moreover, the assistance is needed at both farm, value chain, and territory level, and from different – national, community, public or even private – sources. Overall, given increasing input costs and aging agricultural population, it is a necessity for the whole EU to improve efficiency, mainly through innovation, but from a MS perspective, the competitiveness of their farmers within the EU's Internal Market for agricultural products is the challenge.

6.2. The compliance of the Hungarian "environment" with the requirements

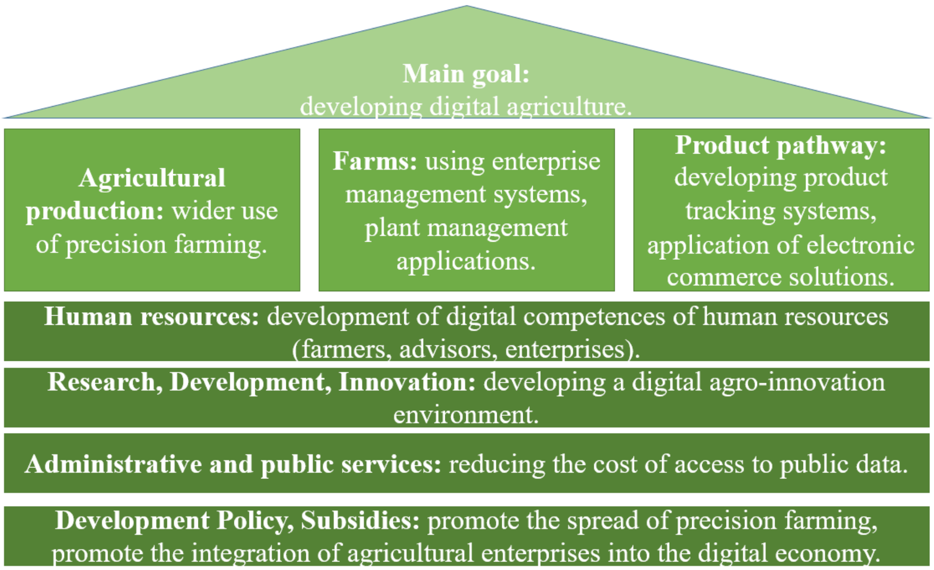
The large input suppliers (like equipment manufacturers and the agro-chemical industry) and the downstream food processing and food service firms generally have the capacity and the background to adopt and to adapt ICTs to address the needs of farmers and consumers. The farm sector, on the other hand, is characterized by the presence of SMEs, many of which may face difficulties in the adoption of ICT-based solutions (FAO 2017). Beyond EU-level actions, government policies can enhance the widespread adoption of appropriate ICTs, including the facilitation of access to "hard" (physical) and "soft" (skills and technical support) infrastructure.

In connection with the necessary and widely accepted mode of improving "soft" skills generally on a domestic level, Gunasekera et al. (2018) emphasize the opposite connection also between agriculture and education. They highlighted the potential use of IoT in agricultural education, as an incentive even to attract new, younger generations. The same impact occurs when digital games are used not only for entertainment but when they are designed for training the player in solving problems in different fields of life or the economy. As the FAO (2017) also highlights, these are simulation platforms that allow learners to experience a number of scenarios and situations, and provide solutions, having a positive impact on analytical skills, learning and recollection abilities, problem recognition and problem-solving.

With a narrower focus on agriculture, in respect of the level of innovation, and the necessary contribution of different (even national) policies and measures, it is a novelty that the Commission proposed *National CAP Strategic Plans* to be developed by the MSs for the next period. Transparently and with the involvement of relevant actors a comprehensive agricultural policy strategy should be developed at the national level in which MSs plan how their measures will contribute to the objectives of the Common Agricultural Policy (EC 2018). This is a key new instrument in the EU's legal proposal for the CAP post-2020 to shift EU agricultural policy to a more performance-based framework (Matthews 2019). Besides this new leeway in the policy with respect to the national conditions, there are no further national possibilities in agricultural policies. Independently from the direct agricultural payments, the targeted financial support of technology improvements remains the sole tool in the hand of MSs to improve agriculture's and its actors' performance.

The *Hungarian Digital Welfare Program* (mentioned later as DJP 2.0 (2017)) serves as a framework to develop the previously mentioned soft skills, the digital competencies, to promote the digital transformation of Hungarian industry and agriculture, with special regard to domestic SMEs and micro-enterprises. The aim of the program is to help businesses take advantage of the benefits of digitization to increase their competitiveness. It emphasizes the role of digitalization also within agriculture, as automatization is a basic condition of increasing productivity and efficiency. The program makes proposals for the digital development of agriculture, such as preparation of Digital Agricultural Strategy, creation of a Digital Agricultural Academy, training of digital consultants and advisors, preparing an Agricultural Data Integration Program, digital development of agricultural enterprises, all encouraging the better exploitation of potential in Hungarian agriculture. Here, it should be emphasized that agricultural advisors and consultants from the national network are supposed to provide trustworthy, independent support, impartially and independently from any input supplier, application provider or dealer. The goal of the Digital Agricultural Strategy (DAS) is to transform and develop the agricultural economy based on digital, intelligent tools and solutions. The Strategy defines three pillars and four cross-bars, as shown in Figure 9.

Figure 9. The structure of the Digital Agricultural Strategy (DAS)



Source: own construction based on Digital Agricultural Strategy (2018)

Beyond the above-mentioned programs, the government has another measure to improve the capitalization of Hungarian agricultural development. Recently the investment-friendly environment contributed to the increasing amount of outstanding credit. Furthermore, within the *Growth Loan Program* (Növekedési Hitelprogram) altogether 480 billion HUF loans were outsourced between 2013–2017, within which the majority – over 50% – has been spent on investments[16] largely directed at technological and efficiency improvements[17].

7. Conclusions

At the beginning of our study, we put emphasis on the present challenges of agriculture, with a focus on Hungarian farmers. As discussed, there are more ways to address these challenges. Here our focus was on the technological development of agriculture, from which the EU and Hungary are both aiming to get the desired outcome. In the following, the development phases of agriculture – from the technological aspect – and industry have both been introduced and compared. It is shown that their point of intersection is in so-called precision agriculture, but recently with constant technological improvements. Industry 4.0 has brought the real-time capability of reacting and making decisions easier based on data collected due to the interconnectedness of machines, so, as the WEF summarized, it resulted in the "*fusion of technologies that blurs the lines between physical, digital and biological domains*"[18] known widely as Farming 4.0.

The aim of the present study was to see how Hungary is performing in this field. Our empirical research have helped us draw conclusions and create suggestions specific to Hungarian conditions. Especially because the results of the survey had to be interpreted as messages containing urgent deliverables, since they come from the well-educated and younger agricultural generation of Hungary, which meanwhile boasts genuine insight into both the needs and possibilities. As found, there would be an *increasing need for advanced technology* in agriculture because of economic, ecological and social reasons, and although for slightly different reasons, both in the EU and Hungary.

In connection with the role of human expertise in Farming 4.0 technologies, empirical research has revealed different results. As the literature summarizes, level of knowledge already plays an important role in the spread of advanced technology in the primary sector. This has been supported by the field research as well. Compared to the threats arising in the secondary sector in connection with the impacts of Industry 4.0, *technology is not likely to replace personal knowledge and experience* in agriculture. But the required level of knowledge, the need for a higher skilled and better educated workforce, is constantly increasing.

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[16] Data from https://nhp-hitelek-statisztika.mnb.hu/reports/powerbi/NHP?rs:embed=true

[17] https://www.agrarszektor.hu/agrarpenzek/a-2019-es-ev-is-mozgalmasnak-igerkezik-a-mezogazdasagban.12953.html

[18] https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/

Having gained an insight into Hungarian conditions and the impacts of Common Agricultural Policy, it is also a possible revelation that the constraints – labor shortage, water scarcity, increasing input prices, decreasing direct agricultural subsidies – may have a bigger and more effective impact on the future development of Hungarian agriculture compared to the personal intention of catching up with the latest technological developments. The findings of the present research were different from this, but we must not forget that our research summarized the views of the "top farmers" of Hungary: younger and better-educated farmers compared to the Hungarian average agricultural population. On a national level, the constraint is to become more effective and competitive within the Internal Market. If we accept that Farming 4.0 is an adequate and widely accepted measure of this, the improvement of the educational, information, knowledge level, and awareness of the farmers is essential. The Hungarian education system thus has to focus on the improvement of overall readiness in the use of Industry 4.0 technologies with special regard to the agricultural sector as well. If it is possible, here both educational background and the acceptance of advanced technologies is lagging behind levels for the same indicators in society as a whole. Farmers should be educated to see the contribution of the use of advanced technologies not as threats, or as is the general opinion of the majority: as "a harmful difficulty". Attracting younger generations would be of the highest importance, but here the controversial effect is also revealed. Based on the surveys, it is also found that the younger generation considers farming with advanced technologies a more attractive form of work, which traditionally is said to be hard.

Beyond appropriate education and the involvement of new generations, the adequate financial background is also a factor in advanced technologies in agriculture. The lack of financial background should be handled by a re-structured system of financial resources. It is visible that the decreasing level of future direct supports of EU-origin is going to be partially replaced by other sources, like the Horizon program. At this point our opinion considering the EU's plans are ambiguous. On the one hand, we support the transition to an EU-level system which instead of conserving ineffective farming conditions tries to contribute to the necessary endogenous improvement of productivity implemented on farm level. But on the other hand, we fear that such a shift in the supporting system favors those farms that are already at a certain level of development, which is like the "tip of the iceberg" in the case of Hungarian agriculture. If this happens, it will increase the necessity of domestic contributions to the development of the sector.

The EU's subsidies should be – as they partially have been – replaced by widening investment measures on the national level, be they public or private. Thus, the objectives of Digital Agricultural Strategy of Hungary should be coupled with domestic financial support. The favorable loan environment may not be enough or not be sustained in the future, but within the framework of research and development programs, the EU and Hungary are both able to support the technological advancements of farmers without harming international trade processes. In this case the "only" factor that may hinder success is the knowledge level of farmers.

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