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Agricultural Economics

Factors determining the competitiveness of grain production and opportunities for their digital optimization

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Abstract. *Grain production is one of the traditional agricultural sub-sectors in Bulgaria, which has been identified for its comparative advantages. The significant levels of social support provided for these businesses after the accession of Bulgaria to the EU and under the influence of Common Agricultural Policy (CAP) have incited considerable investments in their innovative technological development. Given the significant economic role of this sector in the sectoral development determines the need for studying their competitiveness and analysis of the factors that determine it. The present study investigated the level of competitiveness of Bulgarian grain production during the period 2014-2020 and its determining factors by using the Relative Trade Advantage index in order to identify opportunities for digital optimization. The results showed that Bulgarian grain production is a competitive sector but at the end of the studied period the competitiveness of barley and maize is increasing while the wheat competitiveness is decreasing. Finally, some digital possibilities for increasing the technical efficiency of Bulgarian grain production were revealed.*

Keywords: smart crops, agriculture, technical efficiency

Introduction

Modern agriculture today is pressured to use new digital technologies to produce bigger yields more sustainably. At the same time the agricultural holdings are seeking a better business performance and to achieve a certain level of competitiveness. Changes in this sector over time are vital not only for individuals and regions but for the country as a whole. The continued modernization and automation of industry processes, the use of new digital tools, and information derived from them have a crucial role in economic growth, preservation of the competitive advantages that Bulgaria has in grain production and finding new opportunities for a more effective way of using the limited natural resources.

Grain production always has been a focal point of Bulgarian agriculture. The processes of concentration and specialization of production in the sector have led to a further increase in the significance of wheat, barley, and corn production and trade for maintaining and improving the level of competitiveness of Bulgarian agriculture. Therefore, analyzing the competitiveness level of these three major products is a key to identifying factors that could enhance it which is the goal of this study. The analysis covers the period from 2014 to 2020. The results will reveal the digital possibilities for increasing the technical efficiency of Bulgarian grain production. To achieve this goal, the following tasks need to be addressed: to analyze the level of competitiveness of Bulgarian grain production during the period 2014-2020; to assess the factors

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defining the technical efficiency of grain production, an important determinant of its development; to reveal the digital possibilities for increasing the technical efficiency of Bulgarian grain production.

Material and methods

In the scientific literature, there are different methods and models for assessing competitiveness, depending on the purpose and object of study.

For the purposes of this study, several models have been selected for application to assess the competitive advantages and competitiveness of grain production in Bulgaria, utilizing commercial data. The models are based on the classical economic theory, in particular the concept of the comparative advantages of Ricardo (1817) and Heckscher-Ohlin (Leamer, 1995), which argues that trade flows are the result of differences in production costs and that one country will specialize in the production of a product in which it has a cost advantage.

This paper uses several classical economic models to assess the competitive advantages and specialization of Bulgarian grain production, including:

The Relative Comparative Advantage Index (RCA) formulated by Balassa (1965), which is based on the share of a product in exports on the international market. In order to reveal the degree of specialization of the country in a particular production, it is mandatory to compare the market shares in the export of this product with that of another country. The index is calculated using the following formula:

$$RCA_{i,j} = \left(\frac{X_{i,j}}{X_j}\right) \Big/ \left(\frac{X_{i,w}}{X_w}\right) \quad (1)$$

where: $X_{i,j}$ - the value of the export of the product *i* from the country *j;*

X_j - the value of the total sectoral exports of the country *j*;

$X_{i,w}$ - the value of world exports of product *i*;

X_w - the value of total sectoral world exports.

RCA > 1 reveals the competitive advantages of the country in the sector that produces and exports the product and there are prerequisites for the realization of economies of scale, higher exports, and hence, higher competitiveness. Conversely, RCA < 1 shows a lack of competitive advantage.

Over the years, this index has been criticized for covering only the supply of the product it evaluates; that it serves as an index of specialization (Hoang et al., 2017); that it includes only data on exports and no data on imports; that it does not take into account the dynamics of change in competitive advantage and is asymmetric; that it takes into account the double values of exports for the product and the country.

In 1991, Vollrath proposed an alternative to the Balassa index, known as **the Relative Trade Advantage (RTA)**. With this index, Vollrath tries to eliminate the role of re-exports by including in the assessment of competitiveness the country's share in exports of goods and its share in imports. TRA is calculated by the formula:

$$RTA_{i,j} = RXA_{i,j} - RMA_{i,j} \quad (2)$$

where: $RTA_{i,j}$ is the coefficient of comparative commercial advantage.

$RXA_{i,j}$- index of export advantages,

$RMA_{i,j}$- index of import advantages.

A positive value of the RTA index implies the presence of competitive advantages. Conversely, the negative value of the index indicates the absence of competitive advantages.

Relative Export Advantage Index (RXA)

$$RXA_{i,j} = \left(\frac{X_{i,j}}{X_{kj}}\right) \Big/ \left(\frac{X_{i,w}}{X_{kw}}\right) \quad (3)$$

where: RXA is an index of comparative export advantages;

$X_{i,j}$ - the value of exports of product *i* from country *j*;

X_{kj} - the value of the total export of the other products of the sector in the country *j*;

$X_{i,w}$ - the value of world exports of product *i*;

X_{kw} - the value of total world exports of other products in the sector.

RXA > 1 indicates the presence of competitive advantages of the country in the sector that manufactures and exports the product, while RXA <1 shows the absence of such advantages.

The Relative import advantage index (RMA) is similar to RXA but pertains to imports (M) rather than exports:

$$RMA_{i,j} = \left(\frac{M_{i,j}}{M_{kj}}\right) \Big/ \left(\frac{M_{i,w}}{M_{kw}}\right) \quad (4)$$

where: RMA is an index of comparative import advantages;

$M_{i,j}$ - the value of the import of the product i from the country j;

M_{kj} - the value of the total import of the other products of the sector in the country j;

$M_{i,w}$ - the value of world imports of the product i;

M_{kw} - the value of total world imports of other products from the sector.

In this context, RMA values less than one indicate competitive advantages, hence suggesting higher competitiveness.

With the RTA index, the Vollrath index seeks to eliminate the role of re-exports by including in the assessment of competitiveness the country's share in exports of goods and its share in imports, i.e. covers supply and demand. The presented model also clears the shortcoming related to the double reporting of export values for the product and the country.

The presented models offer the advantage of being able to quickly and easily measure and assess the level of competitiveness within various industries and the country as a whole.

Results and discussion

Competitiveness *of Bulgarian wheat production*

Bulgaria is a traditional wheat producer and exporter. In 2017 and 2019 the country was the 12th largest producer of wheat, despite its relatively smaller size (compared to other countries competing on the international market). In order to fully analyze the competitiveness of Bulgarian wheat production, we have calculated the RXA, RMA, and RTA indexes based on data from FOAStat database of the United Nations.

Bulgarian export of wheat increased in the period after 2015 up until 2020. In 2019 the exports reached over 940 mil. USD and have proven to be a large portion of the country's agricultural exports (Table 1). The calculated RXA index does not follow the same trend as the level of exports and maintained stable levels for the period 2016-2018 due to the increase in Bulgarian agricultural export as a whole as well as the growth of the world's wheat market. In 2020 the level of comparative advantages of Bulgarian wheat exports rapidly declined due to the significant decrease in exports evaluated at over 242 mil. USD.

Table 1. Competitive advantages of Bulgarian wheat export

Year	Bulgarian export of wheat (in 1000 US$)	Bulgarian agricultural export (in 1000 US$)	Worldwide export of wheat (in 1000 US$)	Worldwide agricultural export (in 1000 US$)	RXA index
2014	691335	4763884	47785572	1421471666	4,32
2015	653346	4005396	38736620	1274889546	5,37
2016	767748	4298694	36482609	1287439794	6,30
2017	772544	4434882	39012154	1411311355	6,30
2018	850850	4789077	41066294	1454196904	6,29
2019	940976	5087571	39759555	1444359174	6,72
2020	698083	5199091	44834107	1492211093	4,47

Source: Own calculations based on data form FAOStat of the UN

The ongoing upward trend in the country's wheat exports lays a significant foundation for both the sector's development and the enhancement of individual farms through increased production. Although the farmland in Bulgaria has been expanding, its growth is not significant enough to formulate a trend and create a base for production increase. In that case, most producers will focus their efforts on increasing the technical efficiency of their production in order to increase the overall results from it (Thiam et al., 2001; Binam et al., 2004; Barnes, 2008, among others).

The volume of wheat imports in Bulgaria is traditionally low, typically used to supply local bread and flour producers with varieties of wheat that cannot be produced efficiently in the country. The calculated values of the RMA index (Table 2) have remained low throughout the study period, leaving the overall competitive advantages of Bulgarian wheat production unaffected. Up until 2019, the general rise in agricultural imports corresponded with an increase in wheat imports. However, while agricultural imports continued to grow in 2019, wheat imports saw a rapid decline.

Table 2. Competitive advantages of Bulgarian wheat import

Year	Bulgarian import of wheat (in 1000 US$)	Bulgarian agricultural import (in 1000 US$)	Worldwide import of wheat (in 1000 US$)	Worldwide agricultural import (in 1000 US$)	RMA index
2014	8500	3092262	52895748	1450272219	0,08
2015	6768	2823450	42984391	1317150433	0,07
2016	8084	2959338	40693135	1314600098	0,09
2017	15325	3344180	44778732	1441006950	0,15
2018	14599	3610845	44960379	1500250819	0,13
2019	14314	3873249	44318709	1489969675	0,12
2020	9446	4319708	48806483	1538032608	0,07

Source: Own calculations based on data form FAOStat of the UN

The competitive advantages of Bulgarian wheat production are visualized in Figure 1 as a result of the calculation of the RTA index for the period 2014-2020. The trends seen in the competitive advantages of Bulgarian wheat production are almost entirely caused by trends in the competitive advantages of exports.

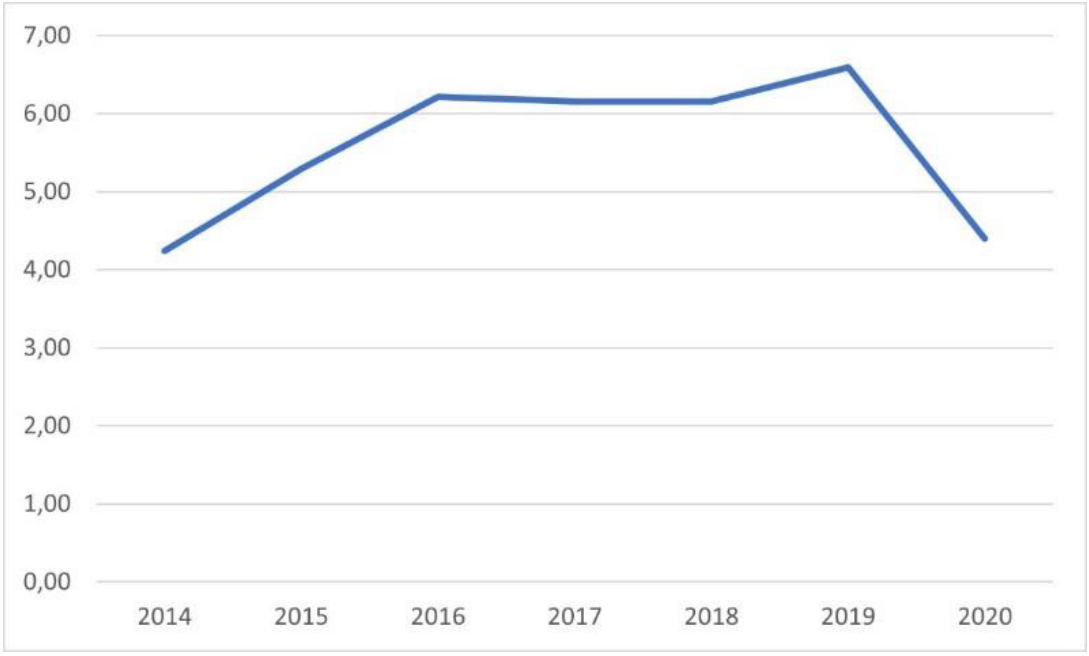

Figure 1. Competitive advantages of Bulgarian wheat production
Source: Own calculations based on data form FAOStat of the UN

Bulgarian wheat production is competitive on the international market throughout the studied period 2014-2020 and has led to an increase in the level of production up to 2019 (6.3 mil. tonnes). In 2020 the production (4.8 mil. tonnes) and thus export rapidly declined, which is evident in the decline in competitiveness of Bulgarian wheat on the international markets.

Competitiveness of Bulgarian maize production

Maize alongside wheat is one of the most common agricultural productions in Bulgaria. The high level of mechanization combined with modern technological innovations characteristic of these productions has led to the concentration of agriculture in the country. The international maize market is highly competitive, with a large number of significant producers. The size of the country prevents it from playing a substantial role in this market.

The exports of maize have fluctuated wildly throughout the studied period with lows of 184 mil USD (2017) and highs of 497 mil USD (2020) (Table 3). This is not evident in the global market and thus leads to significant fluctuation in the competitiveness of Bulgarian exports of maize. At the beginning of the studied period, the comparative export advantages have rapidly decreased due to the corresponding decrease in the levels of exports.

Table 3. Competitive advantages of Bulgarian maize export

Year	Bulgarian export of maize (in 1000 US$)	Bulgarian agricultural export (in 1000 US$)	Worldwide export of maize (in 1000 US$)	Worldwide agricultural export (in 1000 US$)	RXA index
2014	386407	4763884	33139575	1421471666	3,48
2015	214337	4005396	28705509	1274889546	2,38
2016	241283	4298694	29346441	1287439794	2,46
2017	184210	4434882	29989122	1411311355	1,95
2018	276466	4789077	33919288	1454196904	2,47
2019	460578	5087571	35252425	1444359174	3,71
2020	497072	5199091	36750363	1492211093	3,88

Source: Own calculations based on data form FAOStat of the UN

After maintaining the levels of export competitiveness of Bulgarian maize, they declined again in 2017 due to a decrease in exports, reaching the period's lowest point – 184 million USD. Following this low point, exports increased slowly at first in 2018, and then more significantly in 2019, culminating in their highest point in 2020 at 497 million USD. The global market has steadily grown after 2015 and reached its highest point in 2020 as well.

Maize is the most imported product out of the three grain types in this study. Bulgaria is generally uncompetitive in its maze imports with the only exclusion being 2017, when the import levels rose to over 101 mil. USD (Table 4). The amount imported in 2017 is not typical of the country and is in fact almost double the level of the second highest – 2020 with 56.5 mil. USD of maize imports. This trend of rapid import increase is not correlated to any significant change in the global market and can only be correlated to the low levels of exports of maize from Bulgaria in the same year. For the same period – 2016 to 2019 maize production in the country was on a steady rise (from 2.22 mil. tonnes to 4.05 mil. tonnes). All the available market data lead us to the conclusion that these increased imported quantities (356 156 tonnes) have been processed or otherwise used in the country.

Bulgarian maize production is competitive throughout the studied period with the only exception of 2017 (Figure 2).

Table 4. Competitive advantages of Bulgarian maize import

Year	Bulgarian import of maize (in 1000 US$)	Bulgarian agricultural import (in 1000 US$)	Worldwide import of maize (in 1000 US$)	Worldwide agricultural import (in 1000 US$)	RMA index
2014	50142	3092262	38177110	1450272219	0,62
2015	46021	2823450	32747780	1317150433	0,66
2016	37337	2959338	32384037	1314600098	0,51
2017	101368	3344180	33781382	1441006950	1,29
2018	42714	3610845	38085852	1500250819	0,47
2019	49578	3873249	40039906	1489969675	0,48
2020	56557	4319708	40339016	1538032608	0,50

Source: Own calculations based on data form FAOStat of the UN

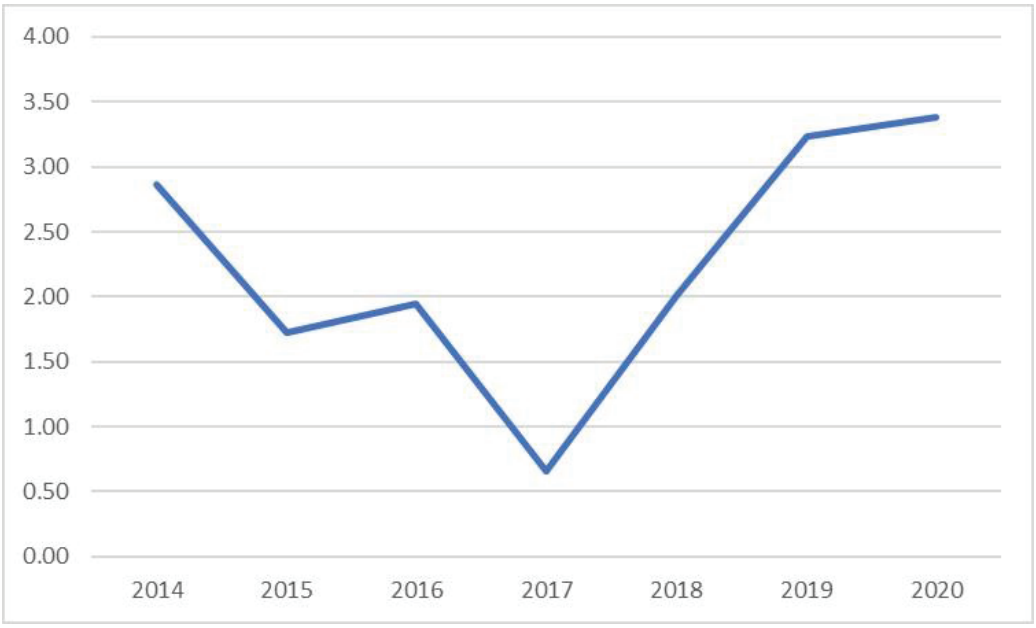

Figure 2. Competitive advantages of Bulgarian maize production
Source: Own calculations based on data form FAOStat of the UN

A trend of decreased competitiveness from 2014 to 2017 led to the aforementioned result. This downward momentum slowed in 2016 due to a slight increase in the value of exports. For the same period, the global maize market has generally maintained its values, which changes to an upward trend after 2017 and reaches its peak in 2020. After 2017 the competitiveness of Bulgarian maize production has steadily increased, more rapidly at first – from 2017 to 2019 and slowly afterwards – from 2019 to 2020. By 2019 Bulgarian maize production has recovered its level of competitiveness on the international market, lost due to the downward trend in the first half of the studied period. These results are very positive for the sector and create a steady base for innovation and the introduction of new digital technology that can further increase the level of technical efficiency of production (Latruffe et al., 2017) and competitiveness of the finished products.

Competitiveness of Bulgarian barley production

Barley has been the least cultivated grain product in Bulgaria, as evident in the values of exports (Table 5). Despite the lower production, Bulgarian barley exports are competitive, but their advantages are declining throughout the studied period with the only exception of 2016 when the decrease in barley exports did not lead to a decrease in its competitiveness due to the international market for the product rapidly shrinking.

Table 5. Competitive advantages of Bulgarian barley export

Year	Bulgarian export of barley (in 1000 US$)	Bulgarian agricultural export (in 1000 US$)	Worldwide export of barley (in 1000 US$)	Worldwide agricultural export (in 1000 US$)	RXA index
2014	112907	4763884	7838053	1421471666	4,30
2015	74584	4005396	7829076	1274889546	3,03
2016	70028	4298694	6164739	1287439794	3,40
2017	55113	4434882	6962403	1411311355	2,52
2018	53012	4789077	7664835	1454196904	2,10
2019	49026	5087571	6532884	1444359174	2,13
2020	65436	5199091	7411453	1492211093	2,53

Source: Own calculations based on data form FAOStat of the UN

Barley exports from Bulgaria increased in 2020 which led to an improved position in the growing international market, creating a positive trend for the future and a base for a future study.

Barley imports in Bulgaria traditionally have very low levels, starting from almost 200 thousand USD in 2014 and reaching a little over 4.6 million USD in 2016 (Table 6). The global barley market has been stable since 2017. In 2016 there was a sharp shrinking in the global market, due to trends with larger exporters.

Bulgarian barley has been competitive in the international market throughout the studied period, as evident in Figure 3, which visualizes the calculations of the RTA index.

Table 6. Competitive advantages of Bulgarian barley import

Year	Bulgarian import of barley (in 1000 US$)	Bulgarian agricultural import (in 1000 US$)	Worldwide import of barley (in 1000 US$)	Worldwide agricultural import (in 1000 US$)	RMA index
2014	199	3092262	8534046	1450272219	0,01
2015	1116	2823450	8479539	1317150433	0,06
2016	4633	2959338	6852978	1314600098	0,30
2017	1864	3344180	7791113	1441006950	0,10
2018	339	3610845	7424804	1500250819	0,02
2019	713	3873249	7375738	1489969675	0,04
2020	378	4319708	7190783	1538032608	0,02

Source: Own calculations based on data form FAOStat of the UN

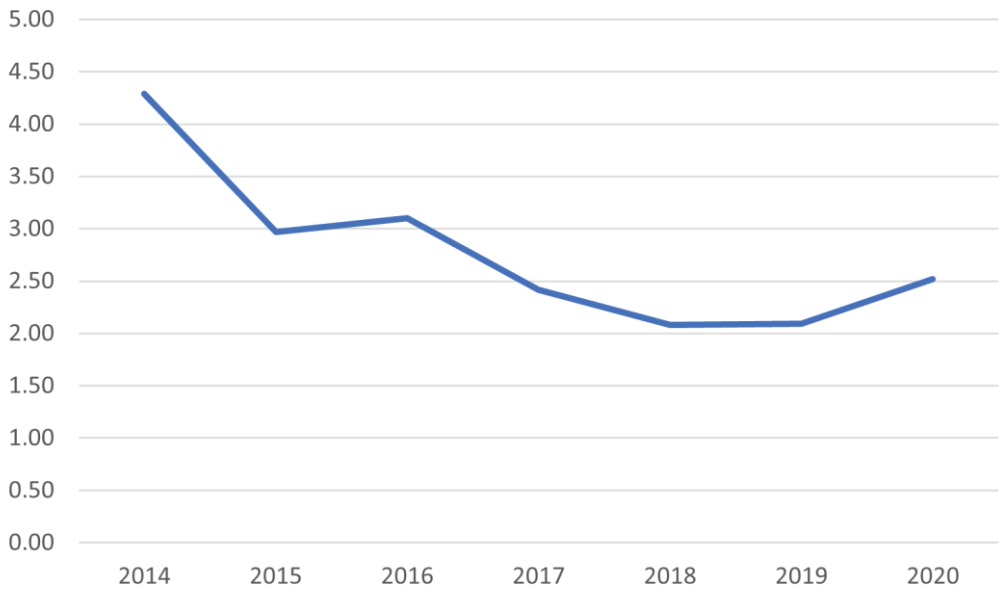

Figure 3. Competitive advantages of Bulgarian barley production
Source: Own calculations based on data form FAOStat of the UN

This competitiveness will not continue in the future if the downward trend is maintained. The slight improvement of Bulgarian barley's position in 2020 can be the beginning of a new upward trend if the level of production is improved. As previously stated, barley is the least produced of the major three cereals in Bulgaria and local support for these productions might be needed in order for them to stay competitive and create a base for improvement of production methods and innovation in the sector.

Possibilities of digital technologies for increasing the technical efficiency of Bulgarian grain production

Agriculture is one of the key sectors of any economy, responsible for the nutrition and employment of mankind. Modern agriculture is facing enormous challenges and structural changes caused by a number of reasons: rapid

population growth (the world's population is projected to grow to 9.7 billion by 2050 (UN, DESA, 2019), which leads to increased demand for food; sustainable and environmentally friendly production; digitalization and automation of production and management processes in the sector. Solutions must be sought to the emerging problems of resource availability, efficient use, building more productive and sustainable food systems, and related to them improvements in business performance and the competitiveness of agricultural holdings.

In the age of digital transformation, part of the way to tackle these challenges is to use digital technologies and innovations, which are already an integral part of our lives (digital-driven system). The introduction of Industry 4.0 in agribusiness and the transition to precision and smart agriculture (Agriculture 4.0) is considered a key asset to achieving these goals. “The concept of precision agriculture is subordinated to the need for optimal allocation of resources, automation of certain processes, and facilitated decision-making that will lead to maximum results in support of enterprises in a competitive sector of the economy” (Stoyanov et al., 2021).

“Digital transformation is most often achieved through the use of cloud technologies, mobile devices, large databases, social media” (Stoyancheva and Angelova, 2021), artificial intelligence, augmented/virtual reality, big data, blockchain, the Internet of Things (IoT) and various micro- and nanoelectronics and robotics. The quality of connectivity is extremely important for the implementation of precise and intelligent agriculture (Bulgaria ranks 26th (along with Greece) among the 27 EU member states in the ranking according to the European Commission's Index on the penetration of digital technologies in the economy and Society (DESI) for 2021), mobility and security.

Smart farming and precision farming use modern technologies, the focus of which is data and their application. Smart farming is focused on efficient solutions that "rely" on the use of different types of data (not just location data) extracted from digital technologies such as big data, GPS, GIS, drones, cloud computing and storage, IoT, etc., to create value (value-driven economy). This will allow stakeholders to have better access to information, resources, finances, improved relationships with end-customers, and training. The ability to extract value from data is now considered a strong competitive advantage.

Digitalization and modern technologies provide opportunities for farms to gain more economic and social benefits directly related to enhancing the agricultural ecosystem. Examples of such technological solutions leading to the improvement of technical and allocative efficiency and management systems are:

Use of mobile applications to access real-time information, which allows better management of production processes and better cost planning. Examples of software with mobile applications offered on the Bulgarian market are TechnoFarm, Agro Office, Arendator BG, and others;

Use of agricultural robots ("agrobots"), GPS navigation, and drones to map agricultural areas, control irrigation, crops, and much more, allows farmers to access real-time information. This allows information-based management decisions to be made. Such solutions offered on the Bulgarian market are TechnoFarm, Agro Office, Tenant BG, Meteobot, CadIS, and others;

The implementation of ERP software systems for resource planning and management allows various functions to be performed through connected programmed modules. The use of this type of systems improves the efficiency of resource management and productivity by standardizing and automating processes, which significantly reduces operating costs, and analyzes and controls departments. On the Bulgarian market the implementation of such systems is carried out by CEE, NIK, and others;

The implementation of technologies based on artificial intelligence, Internet of Things, machine self-learning, and other similar modern technologies allows precision agriculture to carry out various agricultural activities without the direct participation of human capital. These technologies help reduce production and management costs and also allow forecasting through forecasting models, which will allow for timely decision-making and prevention.

Conclusion

Bulgarian grain production has been proven to be competitive based on the methodology selected for this study. As a traditional sub-sector of Bulgarian agriculture, grain production has undergone the same processes of concentration and specialization in accordance with its role in the general development of the sector. Some fluctuations have been found but none of them were correlated to each other and most often were divergent from each other. At the end of the studied period, the competitiveness of barley and maize was increasing while the wheat competitiveness was decreasing. This decline is not part of an overall trend and future prospects remain

positive.

The competitive position of grain production in Bulgaria creates a stable base for innovation in the sector. In recent years, studies have proven that the digitalization of agricultural production has increased the technical efficiency. Bulgarian producers have been exposed to these new technologies. Larger producers have already taken advantage of the large variety of digital tools made available in Bulgaria and laid out in this study.

Future research will be focused on measurements of technical efficiency improvement on a farm level with the introduction of digital tools in grain production. The scale of farms and their ability to participate in the digitalization process must be taken into serious consideration.

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