The Role of Knowledge Capital in Total Factor Productivity Changes: The Case of Agriculture in EU Countries

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Abstract

The present study concerns the impact of knowledge capital on total factor productivity (TFP) changes in 27 European Union (EU) countries. The TFP analysis covered the years 2009-2013. The study conducted was based on a Malmquist productivity index. The knowledge capital was approximated through investments in research and development in the years 2000 and 2008. Furthermore, the study included external benefits resulting from the R&D activities in other countries. In addition to the knowledge capital, the variables approximating human capital were accepted as determinants of TFP, i.e., the percentage of farm managers with full agricultural training and the percentage of farms managed by holders aged 55. The impact of knowledge and human capital on TFP was determined using a linear regression model. The results of the study indicate that the R&D expenditures incurred in the year 2000 are the stimulants of productivity growth, which confirms the assumption that there is a time lag between R&D and its benefits. Moreover, a positive effect on TFP growth was observed for the variable approximating human capital, i.e., the participation of farmers over the age of 55.

Key Words

agricultural productivity; total factor productivity (TFP); knowledge capital; research and development (R&D) activity; European Union (EU)

1 Introduction

Productivity is one of the most important aspects of economic life. It is defined as the ability of production factors to produce an optimal output (LATRUFFE, 2010). A growth in agricultural productivity is considered as a long-run source of real economic growth and higher living standards, and it contributes as well as it to enhancing the competitiveness of a given country's agricultural products on the world markets (HALL and SCOBIE, 2006). It should be stressed that the European Commission considers productivity to be the most reliable long-term indicator of competitiveness (EUROPEAN COMMISSION, 2009).

Numerous scientific works consider the effect of various factors on the increase in agricultural productivity (see LÖÖF and HESHMATI, 2002). However, the effect of knowledge capital on an improvement in productivity has been less extensively investigated. In order to reduce this gap in the literature, we decided to study the impact of knowledge capital on a productivity growth in the agriculture of EU countries. One significant reason for our study was also that the importance of these issues is noted in strategic documents of the EU, including the strategy EUROPE 2020. The reformed CAP also pays more attention to innovation, research and development, and to the transfer of knowledge in the agricultural sector.

The knowledge capital, meaning the results of R&D-related activities, plays a key role in enhancing competitiveness and accelerating an economic growth and transformations, both in a domestic economy and in relation to particular sectors, including agriculture. The effect of R&D activity is technological progress that is regarded as a fundamental, long-term source of competitiveness growth. The manifestations of technological progress include a relative growth in efficiency (including productivity), performance, reduced unit costs, and progress in the implementation of a widely understood innovation (KOWALSKI, 2013).

A very important factor of the productivity growth, which is closely related to knowledge capital, is human capital. It refers to knowledge, educational level, and individual competence of citizens in achieving the assumed tasks and social objectives (BONTIS, 2003). In endogenous growth models developed in the 1980s and 1990s, human capital was introduced into growth equations inter alia as a component of an effective workforce or as an additional production factor (FUENTE and CICCIONE, 2002). In contrast to abstract knowledge, human capital is subject to exclusion, i.e., it is possible to prevent others from using it.

The purpose of this study is two-fold. Firstly, there is an attempt to analyse the changes of the total factor productivity – TFP – in European agriculture. Secondly, we try to find an effect of expenditures on R&D and human capital on the growth of total agricultural productivity in European Union (EU) countries. The focus on non-material factors is due to their increasing role in the development of agriculture similar to other sectors of the economy. Regrettably, no comprehensive theoretical and empirical works devoted to these issues exist. Such studies can provide a basis for formulating an agricultural policy at a national and European level.

This study contributes to the literature in the field of agricultural productivity for three reasons. Firstly, the scope of the study includes a community of 27 EU countries. To the best of authors' knowledge, no research in this field has been conducted so far. Secondly, this study is focused on the changes in total productivity. This measure allows the effects of all main factors of production in agriculture, such as work, land, and capital, to be considered. Thirdly, determinants identified and used in econometric analyses of TFP changes include a relatively large set of variables, approximating the knowledge capital and human capital in agriculture of particular EU countries.

2 Measurement of Productivity in Agriculture

The analysis of productivity is essential from the viewpoint of its improvement. Productivity can be measured by means of partial productivity measures related to the particular production factors, or as total productivity (NOWAK, 2011). Although partial measures are useful and informative, one of their disadvantages is their obvious limitations compared to overall measures (HEADEY et al., 2010). Methods based on the TFP are characterized by a more comprehensive approach to the problem of agricultural productivity.

In order to determine TFP, the growth of total input (land, labor, and capital) is compared to the increase in production (FUGLIE and WANG, 2013; TIEDEMANN and LATACZ-LOHMANN, 2011). The Malmquist index, based on the function of production maximizing, is used inter alia to measure total productivity changes over time (TRUEBLOOD and COGGINS, 2003; FRANCKSEN and LATACZ-LOHMANN, 2006). On the basis of this index, two sources of productivity growth may be distinguished: changes in technical efficiency and changes in production technology. The index is found widely in literature, used equally in terms of farms, regions, countries, or groups of countries. Moreover, this comprehensive method has become increasingly popular, as both researchers and policy makers are interested in measuring not only levels in agricultural productivity but also sources to which its growth is attributed. Additionally, as noted by NEWMAN and MATTHEWS (2007), differences in the rate of productivity growth are the main reason for the different trends in cost competitiveness.

The results of some studies performed in EU countries using the Malmquist index are summarized in Table 1.

Table 1. Review of the research concerning agricultural productivity using the Malmquist index

Author	Period included in the study	Countries included in the study	Results of the study
BRÜMMER et al. (2002)	1991-1994	Poland, Germany and the Netherlands (the case of dairy farms)	Polish farms experienced a productivity deterioration of about 5%, mainly due to a technological regress of about 7%. In the same period the authors identify a productivity increase of about 6% for German farms and of about 3% for Dutch farms.
RUNGSURIYAWIBOON and LISSITSA (2007)	1992-2002	EU 15; EU 10; "Transition countries"	The weighted average TFP growth in European agriculture over the study period was at the level of 1.527 percent per annum which was driven by –0.027 percent in technical efficiency change, 1.496 percent in technical change and 0.054 percent in scale efficiency change.
LATRUFFE et al. (2008)	1996-2000	Polish farms	Over the whole period, the average TFP change and technological change was -2% and -6%, respectively.
FOGARASI and LATRUFFE (2009)	2001-2004	France and Hungary (farms in the dairy and cereal, oilseeds and protein seeds (COP) sectors)	In both the dairy and the COP sectors, Hungarian farms' technology was more productive, despite technological deterioration.
GALONOPOULOS et al. (2011)	1966-2002	32 European and Mediterranean countries that formed part of the Euro-Mediterranean Free Trade Zone	There are two groups of performers: a high productivity group including mainly EU-15 countries and CEECs, and a low productivity group that consists of Albania, Algeria, Libya, Morocco, Tunisia and Syria.

Source: own compilation

A significant issue in the analysis of productivity is to identify the factors determining its growth (LÖÖF and HESHMATI, 2002). Taking into account the fact that classical production factor outlays are considered in Malmquist index calculation, productivity changes should be explained using other variables which may be related to technical changes and the quality of production factors, or to the environment.

The growth of productivity in agriculture is affected by many factors. In their study, RAO et al. (2004) cite quality of the land, the illiteracy rate, government expenditures (percentage of GDP), total export, and total trade (percentage of GDP) as the productivity determinants. ISAKSSON (2007) identified the following as the variables that affect the growth of TFP: education, health, infrastructure, imports, institutions, openness of the economy, competition, financial development, geographical location, and absorptive capacity (including capital intensity). DANQUAH et al. (2011), in turn, considered the following variables as the strongest determinants affecting the growth of TFP: unobserved heterogeneity, initial GDP, consumption share of GDP and trade openness. GRILICHES (1994) points out that productivity growth is associated with an improved quality of human resources, economies of scale, various reallocations of capital between assets, advances in knowledge and innovation, and expenditures on R&D. DARKU et al. (2012) also emphasized the importance of R&D activity and government support for the agricultural sector. Thus, an increase in knowledge assets should be regarded as one of the strategies to increase productivity in every sector of the economy.

In summary, most analyses concerning TFP determinants in agriculture focus primarily on tangible and climatic factors. Few studies take intangible factors into consideration. This study stands out from other studies because it focuses solely on intangible factors of the TFP growth in a broad sample comprising 27 EU member states. In addition, the study takes into account a few variables approximating human capital and knowledge capital. i.e.: a participation of farm managers with full agricultural training, a participation of farmers aged over 55 and public R&D expenditures in agriculture. It is worth noting that most prior studies on the role of intangible factors in the TFP growth limit their subjective scope to one intangible factor.

3 Knowledge Capital as a Factor of Productivity Growth

Knowledge capital is variously defined in the literature. According to the Organization for Economic Co-operation and Development (OECD), knowledge capital results from investments in intangible assets such as R&D, data, software, patents, new organizational processes, firm-specific skills, and designs (OECD, 2013). In many OECD countries, the investments in knowledge capital increased faster than investments in physical capital, i.e., machines, equipment, or buildings. In some countries, investments in knowledge capital far exceed investments in physical capital (OECD, 2013). From the microeconomic perspective, BRAUNERHJELM (2000) defines knowledge capital as accumulated assets in R&D, marketing, software, and education, where returns are appropriated by the (firms) themselves. LAPERCHE (2007) defines knowledge capital as a set of scientific and technical knowledge and information produced, acquired, combined, and systematized by one or several firms for productive purposes. In empirical studies, knowledge capital is frequently approximated by R&D expenditures, patents, and the number of personnel dedicated to R&D activities (DOPESO-FERNANDEZ, 2012). OECD (2002) defines R&D as creative work undertaken on a systematic basis in order to increase a stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications.

As mentioned above, the effect of R&D expenditures comprises new solutions in the area of products and processes. In the context of agriculture, new processes can comprise new methods of production and new methods of storage of goods produced, the use of modern equipment in a manufacturing process, e.g., water saving equipment used in crops irrigation, whereas new products can give rise to new varieties of plants in plant production and improve the genetic potential in animal rearing. Innovations in the agricultural sector lead to an increase in production volume and a reduction in production costs, which in turn leads to an improvement in productivity, while at the same time maintaining the requirements not only of food and health safety but also of modern, ecological safety.

GRILICHES (1979) proposed the following model to incorporate knowledge capital (R&D-generated) into the production function:

$$Y = F(K, N, Z) \tag{1}$$

where Y is a measure of output to the “inputs” K, N, and Z, where K is a measure of the current state of technical knowledge, determined in part by current and past R&D expenditures, N stands for an index of conventional inputs such as labor and capital, and Z stands for all other unmeasured determinants of output and productivity. It is worth noting that in the endogenous growth theory, labor has a quality dimension, which is incorporated into the production function as an additional exogenous variable called human capital (ASTERIOU and AGIOMIRGIANAKIS, 2001).

Unlike physical capital, knowledge capital can contribute to an increased productivity, as initial costs incurred in developing certain types of knowledge are not re-incurred when that knowledge is used again. This may lead to increased benefits of scale in production. Investments in various forms of knowledge capital (such as R&D, patents, and new business processes) also contribute to a creation of knowledge which is transferred to other parts of the economy, again stimulating the growth. Growth accounting studies for EU countries and the United States show that business investment in knowledge-based capital contributes 20%–27% of average labor-productivity growth (OECD, 2013).

Many theoretical studies emphasized the role of international flows of knowledge in a creation of endogenous economic growth. A growing trend in empirical research confirms that international technology spill-over is one of the main sources of productivity growth. However, a relative effect of the flow of knowledge generally decreases with geographical distances, and its impact tends to be more of a domestic range than an international one (KUO and YANG, 2008).

The source of knowledge assets is a formal investment in R&D (HALL and SCOBIE, 2006). The European Commission indicates R&D and innovation as the factors of importance for the growth of competitiveness (EUROPEAN COMMISSION, 2003). The INNOVATION REPORT (2003) emphasizes the importance of a strong base in science and technology, as well as incentives for the transfer of knowledge, R&D, and high standards of education at all levels.

HUSTI (2009) emphasizes in turn that economic growth is generated by a continuous innovativeness in economy, which is based on basic and applied research. Research, development, production, and market together form a system of agricultural production. Thus, there is a close relationship between knowledge and innovations, which are referred to as “a successful development and application of new knowledge” (OECD, 2005). It should be observed that the effects of investment in R&D are usually postponed. Costs incurred currently on R&D can lead to a creation of new knowledge and while its adoption in production systems can sometimes take many years. Therefore, investing in R&D today will probably not contribute to a productivity growth in the next few years, but at some time in the future (HALL and SCOBIE, 2006). The choice of the time-lag between the TFP growth and R&D expenditures is quite problematic. A complete review of literature on this issue is included in the study by NADEEM et al. (2013). For instance, KHAN and AKBARI (1986) and NAGY (1991) considered a 10-year time shift between an agricultural output and an agricultural research. In turn, HUFFMAN (1976) reduced the period of study into aggregate returns to public investments in agricultural research to one year.

Meanwhile, the market failure often leads to an underinvestment in agricultural R&D. The differences in the level of R&D expenditures in particular countries are due to differences in incomes of their residents, a level of economic development, and comparative advantages in science and technology (they reflect not only wealth but also nature of the society) (PARDEY et al., 2006). An important role in this regard is attributed to the state policy and, in the case of EU countries, to the Common Agricultural Policy.

Productivity of a given country is affected not only by domestic expenditures on R&D but also by those incurred in other countries. The import of high-tech goods is undoubtedly one of the most important channels of innovation diffusion (JAKUBIAK, 2002). The estimates of COE and HELPMAN (1995) suggest that the stronger this effect, the more open the economy to a foreign trade. The studies usually assume that all the knowledge transferred between countries is included in R&D, or that the use of knowledge between countries reflects the movement of goods between them (WIESER, 2001). Positive external effects generated by international technology flows depend largely on an ability of a given country (a country of destination) to understand and utilize external knowledge (HALL and SCOBIE, 2006).

Apart from R&D activity, ANTONELLI (1999), following on a NONAKA’S (1994) model, distinguishes additional distinct processes of technological knowledge creation which relate to different forms of knowledge classified along two axes: tacit or codified. He suggests that a technical change may result from both informal and formal learning processes, such as learning-by-doing or by employees' training. It is well established that when a firm introduces new products or new processes, it often faces a problem of insufficient workforce knowledge and skills (TONER et al., 2004). In order to soften these restraints, the firm should invest in workforce training (LUNDVALL and NIELSEN, 1999). The researchers find that both R&D and human capital are important for movements towards, and shifts of, the technological frontier (CANTON at al., 2005). In the case of agriculture, human capital plays a significant role in managing the results of improvement, especially in the suitable management and organization of changes in other production factors, i.e., land and capital (GÓRECKI, 2004). The results of the study of GOŁĘBIEWSKA and KLEPACKI (2005) point out that there is a positive correlation between maintaining a manager education level and the obtained economic results. Also DJOMO and SICOD (2012) prove in their study that some experience and an education level of a manager positively affect an efficiency of production factors in an agricultural holding.

4 Materials and Methods

We calculated agricultural productivity changes and its components for a sample of 27 European Union (EU) countries over the period of 2009-2013, using data from the Eurostat datasets. Our measure of aggregate output includes production value of the agricultural sector at basic price. In turn, aggregate inputs are agricultural labor, capital and land. Labor input is measured in annual work units which correspond to the work performed by one person who is occupied on an agricultural holding on a full-time basis. Capital input is retrieved from capital flow, which encompasses intermediate consumption, i.e., physical inputs for crop and livestock production and overall production inputs, as well as amortization. Land input denotes the stock of an utilised agricultural area.

We deployed a Malmquist index to calculate a total factor productivity (TFP) change. As noted by Caves et al. (1982) the output-oriented Malmquist index is often defined as the geometric means of two indices.

That is:

$$M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)}\right)\left(\frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)}\right)\right]^{1/2} \qquad (2)$$

The notation $D^t(x^t, y^t)$ represents the distance from the period *t+1* observation to the period *t* technology and (x^t, y^t) is the input-output vector in the *t*-th period. A value of M_o greater than 1 indicates TFP growth from period *t* to period *t+1*, whereas a value less than one indicates TFP deterioration.

Once the TFP change had been computed, the next step was to determine its driving forces. We used a linear regression model to identify the determinants of TFP growth. The model is specified as follows (GREENE, 2008):

$$y_i = x_i'\beta + \varepsilon_i \qquad (3)$$

where y_i is a endogenous variable relating to the TFP change of the *i*th country in the years 2009-2013, x_i' is a vector of regressors described in the following, and ε_i is the error term that is assumed to be normally distributed.

In this model, we introduced six independent variables that are considered to be highly relevant for TFP growth:

- x_1 – intensity of expenditures on agricultural R&D in 2000 [share of agricultural GDP]
- x_2 – intensity of expenditures on agricultural R&D in 2008 [share of agricultural GDP]
- x_3 – intensity of external expenditures on agricultural R&D in 2000 [share of agricultural GDP]
- x_4 – intensity of external expenditures on agricultural R&D in 2008 [share of agricultural GDP]
- x_5 – percentage of farm managers with full agricultural training in 2010
- x_6 – percentage of farms managed by holders aged over 55 years in 2010

To take into account the time-lag between the investments in the knowledge capital and their effects in the form of TFP growth, two variables representing flows of knowledge were introduced to the model – the intensity of agricultural R&D in 2000 and 2008. The choice of time-lags was affected by the premises of substantive and pragmatic characters. From the meta-analysis of studies on the productivity of agricultural research, PARDEY et al. (2010) concluded that in more than half of 292 empirical studies, the time-lag range was limited to a maximum of 20 years. On the other hand, systematic data concerning expenditures on R&D in agriculture have been presented by the FAO (2013) in the *FAO Statistical Year Book. World Food and Agriculture* since 2013, and they concern the years 2000 and 2008. This article analyses the effect of R&D expenditure intensity on changes in the TFP in 2009-2013.

Following COE and HELPMAN (1995), we defined the intensity of external agricultural R&D which entered the TFP growth determinants function as the import-share-weighted average of the intensity of domestic agricultural R&D spending of trade partners. This means that R&D spill-overs from country to country are assumed happen through international trade. The following formula is used in the construction of the variable approximating external benefits of the transfer of knowledge and technology (the intensity of external expenditures on agricultural R&D):

$$Ex\mathrm{R\&D}_i = \sum_{j \neq i} w_{ij} \mathrm{R\&D}_j \qquad (4)$$

where $Ex\mathrm{R\&D}_i$ are the intensity of external investments in agricultural R&D in the ith country, $\mathrm{R\&D}_j$ are the intensity of investments in agricultural R&D in the jth country, w_{ij} is the total import-share weight determining the size of R&D transfer from the jth country to the ith country $w_{ij} \in (0,1)$.

Human capital variables used in the analysis were derived from Eurostat datasets and they refer to year 2010.

5 Results and Discussion

Table 2 presents the geometric means of the TFP for individual EU countries covering the years 2009-2013.

An analysis of the indices established for 27 EU member countries indicates a slight (4.5%) increase in the total EU agricultural productivity in the considered period. The results of the research show that an increase in the total productivity level was observed in 20 EU member countries over the studied years, while the analyzed index declined in the other seven countries. However, the differences in the level of the Malmquist index in the group of countries with the positive changes of TFP are relatively small. The highest productivity increase in the examined period can be observed in Italian agriculture, where this index was 1.246. In Czech Republic, Ireland, Greece, France, Italy, Latvia and the United Kingdom the total productivity growth was higher than the average level estimated for all 27 EU countries. Italy, where the TFP index was the highest, reached a result higher by 20.3 p.p. compared to the EU-27.

A total productivity in the agricultural sector decreased to the highest degree in Bulgaria (11.6%), where a 3% decrease in the value of agricultural output and a 9% decrease in a total intermediate consumption[1] was noted in 2013, compared to 2009. Italy, where the dynamics of the total productivity was the highest in the examined period, had an advantage of 36.2 p.p. in absolute terms compared to Bulgaria, while in relative terms it was 41.0%. In the countries of the so-called Old 15, the largest increases in the agricultural productivity, apart from Italy (24.6%), were observed in the United Kingdom (19.7%), and France (15.6%), while in countries such as Luxemburg and Finland, a decrease in TFP was observed in the examined period. Among the new members of the community, the productivity growth in the examined period was observed in the case of seven countries, Slovenia (0.9%), Czech Republic (19.6%), Latvia (4.8%), Lithuania (4.6%), Malta (2.6%), Cyprus (2.1%) and Romania (4.1%). A decrease in the total productivity was observed in the other countries

Table 2. The changes in total factor productivity (TFP) of EU agriculture in years 2009-2013

No.	EU member country	TFP change
1	EU-27	1.045
2	Austria	1.038
3	Belgium	1.036
4	Bulgaria	0.884
5	Cyprus	1.021
6	Czech Republic	1.196
7	Denmark	1.026
8	Estonia	0,990
9	Finland	0.861
10	France	1.156
11	Germany	1.034
12	Greece	1.098
13	Hungary	0.999
14	Ireland	1.087
15	Italy	1.246
16	Latvia	1.048
17	Lithuania	1.026
18	Luxemburg	0.927
19	Malta	1.026
20	Netherlands	1.012
21	Poland	0.91
22	Portugal	1.039
23	Romania	1.041
24	Slovakia	0.974
25	Slovenia	1.009
26	Spain	1.023
27	Sweden	1.014
28	United Kingdom	1.197

Source: own compilation

[1] Total intermediate consumption – total specific costs (including inputs produced on the holding) and overheads arising from production in the accounting year.

which acceded to the Union in 2004 and 2007, but its level was differentiated - in Hungary, it was only 0.1%, while in Bulgaria, it was 11.6%, in Estonia 1.0%, in Poland 9.0% and in Slovakia 2.6%.

Table 3 shows descriptive statistics of the variables used in a regression analysis. The first conclusion to be drawn from the presented data is that there was an increase in the intensity of R&D expenditures in EU countries. R&D intensity rose slightly in 2008 as compared to the year 2000. An analogous trend can be observed in relation to the intensity of external expenditures on R&D. As far as human capital proxies are considered, we find that a small fraction of farmers in EU countries has full agricultural training. Moreover, the structure of farmers' age indicates that the population of farm-holders in EU is getting older.

Table 4 presents the results of an estimation of linear regression model parameters, showing the relationships between the selected factors and changes in total productivity in the EU countries in the period 2009-2013. The backward elimination method has been applied in order to remove the irrelevant variables from the model.

The study demonstrated that all factors associated with knowledge capital and human capital, such as an intensity of internal and external expenditures on R&D activities, participation of farm managers with full agricultural training, participation of farmers aged over 55, positively affected an increase in total agricultural productivity.

Among the above-mentioned factors, the inflow of knowledge capital from abroad to the highest degree positively influenced the total productivity change. As emphasized by JAKUBIAK (2002), the productivity of a given branch can be increased as a result of trade turnover. GUTIERREZ and GUTIERREZ (2003) also believe that foreign agricultural R&D capital stock has a strong effect on a country's TFP. KELLER (1997) claims that if the country has a sufficient absorption capacity, thanks to an import with a large share of advanced technologies, it can gain access to investments in R&D. A destination country does not need to create its own innovations while using foreign inventions. Productivity increases with the amount of imported intermediate products used in domestic production.

Table 3. Descriptive statistics of the variables

Variable	Mean	Std. Dev.	Median	Min	Max
TFP	1.052	0.133	1.026	0.861	1.246
intensity of expenditures on agricultural R&D in 2000	2.652	1.719	2.418	0.371	7.900
intensity of expenditures on agricultural R&D in 2008	2.807	1.988	2.267	0.588	7.590
percentage of farm managers with full agricultural training	13.160	12.190	9.222	0.326	45.909
percentage of farms managed by holders aged over 55 years	49.848	11.074	51.759	26.210	71.379
intensity of external expenditures on agricultural R&D in 2000	3.136	0.542	3.235	2.264	4.647
intensity of external expenditures on agricultural R&D in 2008	3.182	0.679	3.253	2.207	5.269

Source: own compilation

Table 4. Parameters and test values for the linear regression

Variable	Coefficient	*t*-value
Const.	x	-
X_1 intensity of expenditures on agricultural R&D in 2000	0.005***	2.500
X_2 intensity of expenditures on agricultural R&D in 2008	*x*	-
X_3 percentage of farm managers with full agricultural training	0.009***	2.810
X_4 percentage of farms managed by holders aged over 55 years	0.012***	5.707
X_5 intensity of external expenditures on agricultural R&D in 2000	0.092**	2.127
X_6 intensity of external expenditures on agricultural R&D in 2008	*x*	-
Adj. R2	0.978	
F(4,23)	263 (p=0.000)	

Notes: *x* denotes the eliminated variable, ** and *** indicate significance at 5% and 1%, respectively.
Source: own compilation

Another factor which positively affected the growth of agricultural productivity was participation of farmers aged over 55. The results of studies carried out by BALEŽENTIS (2015) lead to similar conclusions. They prove that older farmers managed to achieve a higher efficiency in farm management. The author attributes it to the fact that experienced farmers ensure an optimum structure of expenditure. However, supposedly in the long run this factor (age) can have an adverse effect on the productivity of production factors. This is supported, among other things, by the results of studies carried out by AMOS (2007), according to which an increase farmers' age would lead to a reduction in the efficiency level of farms.

This finding suggests that experience in the management of agricultural production plays an important role in productivity growth, which is the result of the complexity of the production process in this sector, as such experience may be regarded as a substitute for formal education of the farmer (KOZERA, 2010). Similar conclusions were drawn by PROKOPOWICZ and JANKOWSKA-HUFLEJT (2010) who found that there was a positive correlation between farmers' age and land productivity in the sample of Polish agricultural holdings.

As expected, the total productivity was positively affected by the level of farm holders' agricultural training. Education is a key indicator of human capital quality which in turn is an important factor in a creation of the innovations in production. Human capital plays a unique role in the management of growth results, especially in terms of an effective management and an organization of other factors of production, such as land and capital. The research results of MAKKI et al. (1999) confirm this assumption. These authors argue that competences acquired during the process of education increase farmers' ability to process information and allow for proper selection and use of new technologies. Thus, farmers with a full agricultural training or education usually have a better understanding of new technologies and more rational ways of combining resources, and thus they are able to increase the productivity of their farms.

The smallest positive impact on TFP growth in the case of EU agriculture was observed for expenditures incurred on R&D by particular countries. This may be due to problems associated with the statistical analysis of a relationship between R&D and productivity. MAIRESSE and SASSENOU (1991) point out that these problems result from the fact that R&D effects are intrinsically uncertain, often occur with long lags, may vary significantly from one firm or sector to another, and change over time. They may also be overshadowed by the effects of other factors of production and the productivity which occur simultaneously and may largely dominate them.

It should also be emphasized that in the case of domestic and external expenditures on R&D, there is a time shift for the effects of these types of actions. On the basis of the data of 2000 and 2008, the effect of these variables was examined in this study, and the impact of both internal and external expenditures on R&D in 2008 on TFP appeared to be insignificant. It can thus be concluded that in the agricultural sector of the EU, both domestic effects of R&D and an adaptation of innovations from abroad were shifted. As emphasized by HALL and SCOBIE (2006), it is obvious that the results of the currently performed research will not be immediately used in agriculture and will not be immediately reflected in higher productivity. They increase the knowledge capital held by a country, which could potentially contribute to productivity growth. KUO and YANG (2008) draw our attention to the fact that the effectiveness of the inter- or/and intranational spill-overs depends largely on the absorption capacity of a country/region from which innovations arise. This means that an absorption capacity is a prerequisite for the positive impact of international spillovers of regional externalities on the economy of the host region (Kuo and Yang, 2008).

6 Conclusions

This study presents measurements of changes in total agricultural productivity in 27 EU countries within the years 2009-2013. Additionally, an impact of knowledge capital and human capital on TFP was conducted using a linear regression model.

The results of the study show that a slight increase in the total agricultural productivity in the examined period was noted for the entire population of 27 EU countries. Taking into account the factors determining the changes in TFP, it should be noted that all of the tested factors related to knowledge capital and human capital in agriculture – an intensity of domestic and external expenditures on R&D, a participation of farm managers with agricultural training, a participation of farm holders aged over 55 – were the stimulants, while the strongest positive impact was determined by external expenditures on R&D.

The results obtained allow for a formulation of numerous recommendations in the range of knowledge capital use to raise agricultural productivity.

Firstly, it should be emphasized that there is a need for an increase in public investments in R&D, allowing the creation of technical progress in agriculture. According to the research results of MAKKI et al. (1999), only R&D activity financed with public funds has a decisive effect on the changes in agricultural productivity. This is due mainly to the presence of positive external effects related to the diffusion of new technologies (KIJEK and KIJEK, 2010). However, planning and evaluation of activities in this area should take into account the fact that there is a time shift of the effects of investments in the knowledge capital in relation to expenditures for this purpose. Therefore, the effectiveness of these types of expenditures should be assessed only from a long-term perspective. Additionally, education policy should be focused on improving the qualifications of farmers. The investments in the human capital contribute directly to increased agricultural productivity by improving the utilization of the available factors of production, and greater ability absorption of new technologies. Growth of agricultural productivity through the use of knowledge capital can be stimulated by an implementation of the Horizon 2020 Framework Programme, which is one of the largest programmes for R&D in the history of the EU.

The paper is not exempt from some limitations. The main drawback pertains to a one-dimensional approximation of knowledge capital by R&D expenditures. According to the literature on economics of innovation, knowledge capital may be approximated by other measures, such as a number and quality of patents, a number of personnel dedicated to the R&D activities measured, etc. Another shortcoming of the paper concerns the choice of the time-lag between R&D expenditures and the TFP growth. As mentioned previously, our choice of the time-lag was based on the premises of substantive and pragmatic characters. However, there is a vast body of empirical studies that produce mixed results on the postponed effects of R&D investments. Last but not least, there is a drawback which relates to a construction of an external knowledge variable introduced to our model. In this case we used a common approach proposed by COE and HELPMAN (1995) which does not take into account a spatial pattern of cross-country knowledge spill- overs. So, in order to overcome these limitations, future studies on the relation between knowledge capital and the TFP growth should use a broader set of knowledge capital proxies. Moreover, they ought to try testing different time-lags between the investments in knowledge capital and their productivity effects. Finally, the special dependency of knowledge diffusion should be addressed in the methodological part of these studies.

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