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Microeconomic appraisal of pork market indicators including correlation matrices and developmental trend models in the EU

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Abstract

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The aim of this article is to evaluate microeconomic aspects of the pork market including correlation matrices of its indicators and key developmental trends in the member states of the European Union. Pig breeding and pork production plays an important role in agribusiness of many EU countries. Production is geographically allocated very unevenly where more than two thirds of pigs are concentrated in Germany, Spain, Denmark, France, the Netherlands and Poland. Pig production and pork market are highly specialized across borders, such as Denmark for piglet breeding or Spain for fattening. Mixed producers such as Belgium, Denmark, Germany and the Netherlands then form one of the main production areas of this commodity. There are also significant structural differences between pig farming in the established and the new member states of the European Union. The highly competitive market includes large enterprises using modern infrastructure with concentrated production enabling to widely benefit from economies of scale but also a high number of small farmers. High competitiveness of key producers is also reflected in international trade patterns. Nevertheless, the decline in the number of pigs in a number of countries can be attributed to low prices and lower profitability. The contribution of this article is to be found also in models of development trends in pork production and it revealed several correlations of pig breeding and other indicators that were calculated on the basis of relevant indicators from the member states of the European Union.

Keywords: market; pork; commodity vertical; input price; regression and correlation analysis; development trend models

Introduction

The members of the European Union are attempting to find its future direction to create conditions for a long-term competitiveness in a global environment and at the same time to guarantee and maintain existing social level within the present social model. Previous evolution of the pork market worldwide including the development of pigs' livestock and pork production in key countries was depicted for instance by Soare & Chiurciu (2017), Rotaru (2018) or Windhorst (2018). International competition in the European Union is very high and smaller pork market producers have to compete with large enterprises with modern infrastructure, concentrated production that are benefiting from high economies of scale. Those technological advances have been a key reason for productivity growth in pork and also beef industries that were studied and compared by Maples et al. (2019) and this perspective allows for the consideration of what the future might hold for each industry, and how technological innovations can influence product quality and trade issues or the entire market structure. The objective of the article is to evaluate economic aspects of the pork market in the European Union including correlation matrices of its indicators and key developmental trends in member states of the European

Union. The expected scientific contribution of the article is to be found in revealed correlations of pig breeding and other indicators and calculations of development models of pork meat in the member states of the European Union where a starting point for it presents an extensive analysis of the pork market in the European Union.

Material and Methods

The research starts with an analysis of the development of the pork market in the European Union, which presents a precondition for following correlation and regression analysis for selected indicators of pig breeding and a calculation of development models of pork meat. Issues of competitiveness and technology in agribusiness were previously dealt by for instance by Dvořáková & Palát (2015). Furthermore, correlation matrices and developmental trends for chosen indicators of pig breeding were calculated. In this paper, particular characteristics of tightness of the dependency of variables are calculated. Conjugate regression lines show the same values of the tightness dependency characteristics, the correlation coefficient $r_{yx} = r_{xy}$, determination coefficient $r_{yx}^2 = r_{xy}^2$ (at the first place in this index is stated variable thought to be dependent). The correlation index I_{yx} is a dependency tightness characteristics for any type of regression function (for simple as well as multiple dependencies of variables). Its second power is determination index I_{yx}^2. Determination index multiplied by 100 presents the explanation percentage of the calculated regression function – how the changes of dependent variable Y are explained by the changes of independent variable(s). The equations for models of development trends of meat production (pigs) were calculated in all member states of the European Union.

The equation for a linear model is: $y_t = a_{yt} + b_{yt}t$.

The equation for a quadratic model is: $y_t = a_{yt} + b_{yt}t + c_{yt}t^2$

The equation for a cubic model is: $y_t = a_{yt} + b_{yt}t + c_{yt}t^2 + d_{yt}t^3$

To carry out correlations and developmental trends of the given indicators we use annual data regularly published in the European Union. Following sources of data were used in this article: the European Statistical Office Eurostat (2021), CZSO (2021) and eAGRI (2021). Further data is based also on survey on the structure of agricultural farms in the countries of the European Union (FSS, 2018). All statistical models in this article were calculated by means of the statistical software Unistat. A previous comparative study on the pork market in the European Union was published for instance by Soare et al. (2017). The current knowledge basis and important state-of-the-art issues for this research topic are described in next paragraphs.

Results and Discussion

The first part of this article focuses on main features of the pig market and deals with an evaluation of the current situation and development of the pork market in the countries of the European Union. Let's start with a look at the countries and areas of pig production in 2018. The highest share of pigs in the European Union can be found in following countries: Spain (20.8%), Germany (17.8%), France, (9.3%), Denmark (8.5%), the Netherlands (8.1%) and Poland (7.4%). Over the last eight years, pig meat production in the European Union increased by 6.7% and reached 23.846 mln tonnes. The key pig meat producing countries of the European Union are Germany and Spain producing 5.3 and 4.5 mln tonnes respectively. Figure 1 presents the per cent share of EU total pig meat production in 2018 based on tonnes of carcass weight. Sharpest rises in pig meat production were recently observed in Netherlands and Spain despite that the average real-terms price of pigs in the EU deeply dropped by 13%, back down to levels similar to the previous lows of 2010 and 2015 (Cook, 2021).

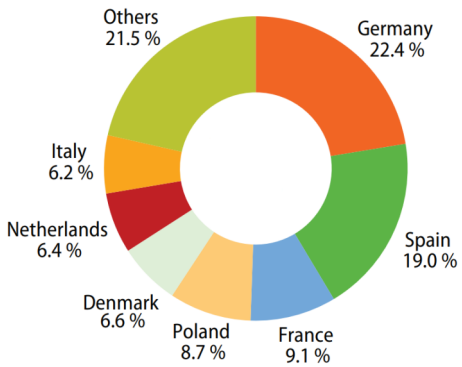

Fig. 1. Per cent share of EU total pig meat production in 2018 based on tonnes of carcass weight

Source: Cook (2021)

To determine the most important production areas of pigs, it is appropriate to use regional data on livestock, which are shown in Figure 2. The main production area is located between Germany (North Rhine-Westphalia and Lower Saxony) and Belgium (Flanders) and accounts for 30% of pigs. However, there are also other important regions, such as Catalonia, Murcia (Spain), Lombardy (Italy), Brittany (France) and some areas of central Poland and northern Croatia.

Pig production is geographically spread in a number of countries where more than two thirds of pigs are concentrated in Germany, Spain, Denmark, France, the Netherlands and Poland. At the regional level (NUTS 1), more than half of pigs

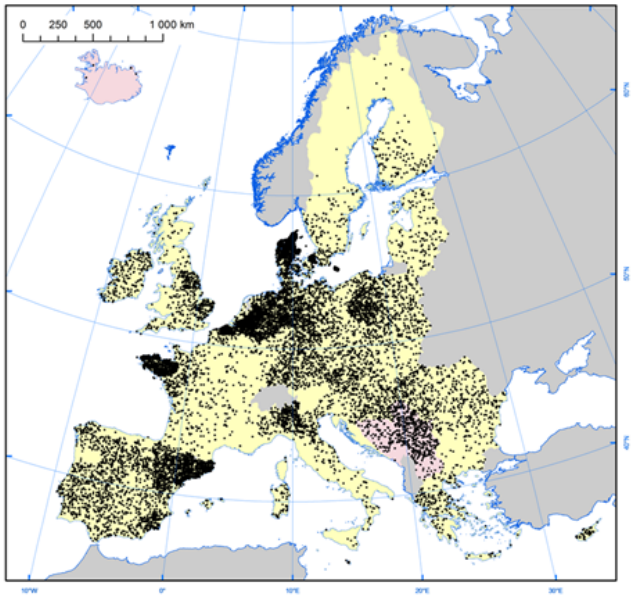

Fig. 2. Production areas of pigs in the regions of the European Union
Source: FSS (2018)

Fig. 3. Net exports scheme of piglets within the countries of the European Union
Source: FSS (2018)

are concentrated in eleven regions, all of which are located in these six countries. Klein (2018) describes fragile links within the transnational networks between Germany and Central and Eastern European countries. There are structural differences between pig farming in the EU-15 and the new Member States (EU-13). In the EU-13, there are only around three per cent of breeding pigs out of their total number in the EU but there are a high proportion of pigs in small herds. The size of herds in particular countries is also affected by the trade in live pigs up to 50 kg; see Figure 3 with an indication of main trade flows. Germany is the main importer of young pigs, with more than a half of the total in the EU, followed by Poland with little bit less than a quarter of the total.

Germany and Poland are also the highest importers of breeding and slaughter animals see Figure 4. Denmark is the main exporter of piglets in the EU (more than a half of the total). However, exports of pigs for slaughter are much more divided between EU Member States.

Based on the above cartograms, it can also be noted that pig production is highly specialized across borders, such as Denmark for piglet breeding or Spain for fattening. Mixed producers such as Belgium, Denmark, Germany and the Netherlands then form one of the main production areas within the European Union. Regarding the development of pork production in the countries of the European Union, pork data reflect production from the slaughter of live pigs in a country (gross indigenous production). This is a gross domestic production that includes

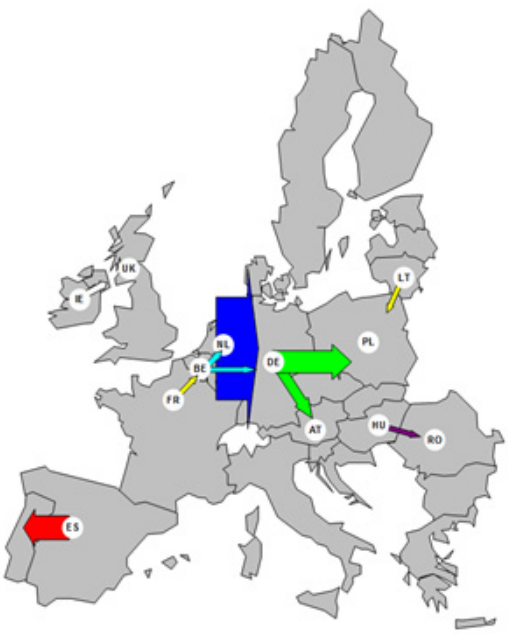

Fig. 4. Net export scheme of pigs for slaughter within the countries of the European Union
Source: FSS (2018)

net production of slaughtered animals plus the balance of intra-EU trade and foreign trade (exports minus imports) with these animals, see GIP (2021) or Bečvářová (2014). It should be noted that there is not a full equality between fattening and slaughter categories. Seasonal variations in production are caused by lower fertility of sows in summer, as well as other cultural factors, such as various traditional celebrations. Pork production has an economic cycle of less than two and a half years, although its impact on farmers' decisions is lower than in the case of other major economic changes. More than half of the pork in the EU comes from four countries (Germany, Spain, France and Poland). Exports outside the EU were mainly focused on Russia, China, Japan and South Korea. Production and distribution chains for pork in Europe have been addressed, for example, by Brinkmann et al. (2009).

The issue of market prices in this sector is of key importance. Enterprise support policies were dealt for instance by Jurčík (2007) or Novosák et al. (2018). The decline in the number of pigs in some countries can be attributed to low profitability. The reduction in the number of sows has been greater than expected in the last decade, according to a survey of EU livestock. During this period, there were also high fluctuations in prices of feed, which led to high prices for cereals and compound feed. This caused a very difficult situation, which forced a significant number of pig farmers to stop the production. While large producer countries are increasing their production (Germany, Spain) or production has stagnated (France), in a number of traditional EU-13 producer countries there has been a decline in production in the last decade (Romania, Hungary, the Czech Republic). For similarities with beef production, compare with Palát et al. (2012). However, in Romania the negative trend gradually reversed despite the initial threatening decline (similarly later in Hungary). The only exception among large producers within the EU-13 is Poland, where the decline in production was only slight and a positive growth trend gradually emerged. The topics of slaughter pigs and pork meat in agribusiness were dealt in the past for example by Tamáš & Bečvářová (2013), Urbánek et al. (2017) or by Palát & Palátová (2020) in the Czech Republic.

Correlation analysis for indicators of pig breeding in the countries of the European Union

This subchapter is dedicated to potential correlations of several indicators of pig breeding in the countries of the European Union. The factual material used for the following calculations comes from data available from Eurostat (2021). The methods include development trends of indicators and regression and correlation analysis for following indicators: meat production (pigs); price index of agricultural products: pigs and number of pigs. The comparison of the situation in the countries of the European Union for the indicator of meat production (pigs) is shown in the cartogram in Figure 5. Table 1 presents calculated correlation matrix for indicators of pig breeding in particular member states of the European Union.

Regarding the calculated correlations, most frequent is a positive correlation between the number of pigs and pork production. One asterisk indicates results that are statistically significant at the significance level $\alpha = 0.05$ and two asterisks indicate results that are statistically highly significant at the significance level $\alpha = 0.01$. This correlation is statistically highly significant at the significance level $\alpha = 0.01$ in the Czech Republic, Slovakia, Slovenia, Spain, France, Finland, Sweden, but also in Malta and Cyprus. It is still statistically significant at the significance level $\alpha = 0.05$ in Greece and

Table 1. Correlation matrix for indicators of pig breeding in the countries of the European Union

	M – P	M – N	N – P
Belgium	0.2106	0.6391*	0.5636
Bulgaria	-0.4518	0.2716	-0.8249**
Czech Republic	-0.4470	0.9439**	-0.3817
Denmark	-0.4749	0.2670	-0.5243
Germany	-0.3874	-0.2258	0.7415*
Estonia	–	-0.6510*	–
Ireland	0.5725	-0.0444	-0.2686
Greece	0.7383*	0.7831*	0.9033**
Spain	0.1257	0.9646**	-0.0804
France	-0.5030	0.7704**	-0.5542
Croatia	-0.2288	0.3268	-0.3169
Italy	-0.2647	0.2737	-0.7360*
Cyprus	0.0642	0.9628**	0.0925
Latvia	0.0124	0.3495	0.0936
Lithuania	-0.1271	0.0863	0.0742
Luxemburg	-0.1027	0.5195	-0.1491
Hungary	-0.8362**	0.7469*	-0.7913**
Malta	-0.8678**	0.8550**	-0.7728**
Netherlands	-0.0212	0.3246	0.0158
Austria	-0.2543	0.5615	-0.5888
Poland	-0.5955	0.3080	-0.7675**
Portugal	-0.9117**	-0.0467	-0.2940
Romania	-0.6297*	0.5548	-0.7609**
Slovenia	-0.7113*	0.9098**	-0.7863**
Slovakia	0.1366	0.8652**	0.2376
Finland	-0.5414	0.9570**	-0.5044
Sweden	-0.4699	0.9507**	-0.5011
United Kingdom	0.2062	-0.1490	-0.6677*

Source: own calculations

Note: M – meat production: pigs; P – price index of agricultural products: pigs; N – number of pigs; * – significance level $\alpha = 0.05$; ** – significance level $\alpha = 0.01$

Table 2. Models of development trends of meat production: pigs in the reference period in Belgium, Bulgaria, Czech Republic, Denmark, Germany, Estonia and Ireland

	Model	a_{ytytyt}	b_{ytytyt}	c_{ytytyt}	d_{ytytyt}	I_{ytytyt}
Greece	1	11.811984	-0.29089510	–	–	0.9421**
Greece	2	11.3025	-0.072544455	–0.016796203	–	0.9567**
Greece	3	11.743606	-0.41347258	0.046218947	–0.0032315462	0.9613**
Spain	1	67.389333	1.2905769	–	–	0.8475**
Spain	2	72.147795	-0.74876398	0.15687237	–	0.9040**
Spain	3	64.076848	5.4892206	–0.99612004	0.059127816	0.9692**
France	1	35.191893	-0.53507342	–	–	0.8510**
France	2	37.224022	-1.4059857	0.066993256	–	0.9111**
France	3	35.077939	0.25270868	–0.23959007	0.015722222	0.9385**
Croatia	1	34.870818	-1.7245104	–	–	0.8254**
Croatia	2	39.297772	-3.6217767	0.14594355	–	0.8525**
Croatia	3	32.052383	1.9781392	–0.88911199	0.053079772	0.8826**
Italy	1	26.990075	-0.12383216	–	–	0.3117
Italy	2	25.3475	0.58012887	–0.054150849	–	0.5202
Italy	3	23.472383	2.0293944	–0.32202458	0.013737114	0.6035
Cyprus	1	87.065530	-1.8307482	–	–	0.7742**
Cyprus	2	75.732	3.0264790	–0.37363286	–	0.9123**
Cyprus	3	67.323373	9.5254538	–1.5748651	0.061601657	0.9420**
Latvia	1	18.305712	-0.53546853	–	–	0.5799*
Latvia	2	23.385454	-2.7125009	0.16746403	–	0.8021**
Latvia	3	19.814040	0.047822751	–0.34273798	0.026164206	0.8417**

Source: own calculations

Table 3. Models of development trends of meat production: pigs in the reference period in Greece, Spain, France, Croatia, Italy, Cyprus and Latvia

	Model	a_{ytytyt}	b_{ytytyt}	c_{ytytyt}	d_{ytytyt}	I_{ytytyt}
Greece	1	11.811984	–0.29089510	–	–	0.9421**
Greece	2	11.3025	–0.072544455	–0.016796203	–	0.9567**
Greece	3	11.743606	–0.41347258	0.046218947	–0.0032315462	0.9613**
Spain	1	67.389333	1.2905769	–	–	0.8475**
Spain	2	72.147795	–0.74876398	0.15687237	–	0.9040**
Spain	3	64.076848	5.4892206	–0.99612004	0.059127816	0.9692**
France	1	35.191893	–0.53507342	–	–	0.8510**
France	2	37.224022	–1.4059857	0.066993256	–	0.9111**
France	3	35.077939	0.25270868	–0.23959007	0.015722222	0.9385**
Croatia	1	34.870818	–1.7245104	–	–	0.8254**
Croatia	2	39.297772	–3.6217767	0.14594355	–	0.8525**
Croatia	3	32.052383	1.9781392	–0.88911199	0.053079772	0.8826**
Italy	1	26.990075	–0.12383216	–	–	0.3117
Italy	2	25.3475	0.58012887	–0.054150849	–	0.5202
Italy	3	23.472383	2.0293944	–0.32202458	0.013737114	0.6035
Cyprus	1	87.065530	–1.8307482	–	–	0.7742**
Cyprus	2	75.732	3.0264790	–0.37363286	–	0.9123**
Cyprus	3	67.323373	9.5254538	–1.5748651	0.061601657	0.9420**
Latvia	1	18.305712	–0.53546853	–	–	0.5799*
Latvia	2	23.385454	–2.7125009	0.16746403	–	0.8021**
Latvia	3	19.814040	0.047822751	–0.34273798	0.026164206	0.8417**

Source: own calculations

Table 4. Models of development trends of meat production: pigs in the reference period in Lithuania, Luxembourg, Hungary, Malta, the Netherlands, Austria and Poland

	Model	a_{ytytyt}	b_{ytytyt}	c_{ytytyt}	d_{ytytyt}	I_{ytytyt}
Lithuania	1	30.098545	–1.1755454	–	–	0.6446*
Lithuania	2	40.262636	–5.5315844	0.33507992	–	0.8547**
Lithuania	3	44.842050	–9.0709850	0.98928194	–0.033548821	0.8706**
Luxembourg	1	18.198303	0.54113286	–	–	0.7096**
Luxembourg	2	23.366772	–1.6739255	0.17038911	–	0.9846**
Luxembourg	3	23.096848	–1.4653028	0.13182850	0.0019774669	0.9849**
Hungary	1	48.043363	–0.93651748	–	–	0.6299*
Hungary	2	54.974045	–3.9068096	0.22848401	–	0.7857**
Hungary	3	43.619020	4.8694186	–1.3936624	0.083186998	0.9332**
Malta	1	20.435924	–0.76439860	–	–	0.9525**
Malta	2	20.072318	–0.60856743	–0.011987012	–	0.9536**
Malta	3	19.480393	–0.151072871	–0.096547619	0.0043364413	0.9548**
Netherlands	1	73.492606	0.86634265	–	–	0.8208**
Netherlands	2	77.759727	–0.96242357	0.14067432	–	0.9163**
Netherlands	3	76.042252	0.36500196	–0.10467920	0.012582232	0.9225**
Austria	1	62.089984	0.079027972	–	–	0.1990
Austria	2	58.731409	1.5184175	–0.11072227	–	0.8748**
Austria	3	58.493232	1.7025029	–0.14474753	0.0017448847	0.8757**
Poland	1	50.170303	–0.32044405	–	–	0.2932
Poland	2	57.327522	–3.3878239	0.23595229	–	0.7219*
Poland	3	52.746252	0.15301128	–0.41851487	0.033562419	0.7730*

Source: own calculations

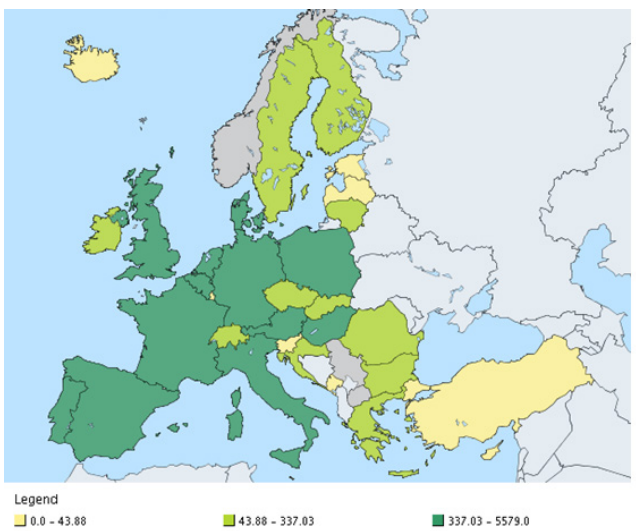

Fig. 5. Meat production: pigs in thousands of tonnes in the countries of the European Union
Source: Eurostat (2021)

Hungary. There is also a negative correlation between the number of pigs and the price index of agricultural products: pigs, although statistically highly significant at the significance level $\alpha = 0.01$ is only in Bulgaria, Romania, Poland, Hungary, Slovenia, Greece and Malta. In Germany, Italy and the United Kingdom, this dependence is statistically significant only at the significance level $\alpha = 0.05$. A negative correlation between pork production and the price index of agricultural products: pigs is less common, when statistically highly significant at the level of significance $\alpha = 0.01$ is in Hungary, Portugal and Malta and statistically significant at the level of significance $\alpha = 0.05$ is then in Greece, Romania and Slovenia.

Models of development trends of meat production: pigs in the countries of the European Union

In this part of the article, models of development trends of meat production (pigs) were calculated in all member states of the European Union. An equation for the linear development trend model is: $y_t = a_{yt} + b_{yt}\, t$. An equation for the quadratic development trend model is: $y_t = a_{yt} + b_{yt}\, t + c_{yt}\, t^2$. An equation for the cubic development trend model is: $y_t = a_{yt} + b_{yt}\, t + c_{yt}\, t^2 + d_{yt}\, t^3$. Table 2 to Table 5 show models of concrete development trends in particular countries.

The parameters of models of development trends of meat production (pigs) were calculated in the reference period and with a few exceptions most of the calculated I_{yt}

Table 5. Models of meat production trends: pigs in the reference period in Portugal, Romania, Slovenia, Slovakia, Finland, Sweden and the United Kingdom

	Model	a_{ytytyt}	b_{ytytyt}	c_{ytytyt}	d_{ytytyt}	I_{ytytyt}
Portugal	1	32.671242	0.20962937	–	–	0.4323
Portugal	2	30.328318	1.2137397	–0.077239260	–	0.6515
Portugal	3	25.930232	4.6129929	–0.70553724	0.032220409	0.8847**
Romania	1	22.825272	–0.77538811	–	–	0.5657*
Romania	2	30.52975	–4.0773069	0.25399375	–	0.8003**
Romania	3	28.749222	–2.7011481	–0.000367354	0.013044159	0.8049**
Slovenia	1	17.382803	–0.68340559	–	–	0.8788**
Slovenia	2	19.504363	–1.5926458	0.069941558	–	0.9201**
Slovenia	3	15.903959	1.1900840	–0.44440187	0.026376586	0.9700**
Slovakia	1	24.783136	–1.6613286	–	–	0.9308**
Slovakia	2	30.468590	–4.0979520	0.18743256	–	0.9845**
Slovakia	3	28.752353	–2.7714828	–0.057744200	0.012573167	0.9866**
Finland	1	40.216409	–0.41671678	–	–	0.8324**
Finland	2	39.27175	–0.011862887	–0.031142607	–	0.8538**
Finland	3	35.991737	2.5232384	–0.49971583	0.024029396	0.9569**
Sweden	1	29.260833	–0.44161538	–	–	0.9161**
Sweden	2	29.150181	–0.39419330	–0.003647852	–	0.9164**
Sweden	3	27.615131	0.79223766	–0.22294078	0.011245791	0.9401**
United Kingdom	1	10.642287	0.32919930	–	–	0.9731**
UnitedKingdom	2	11.139568	0.11607917	0.016393856	–	0.9843**
United Kingdom	3	11.336858	–0.03640535	0.044578199	–0.00144535	0.9850**

Source: own calculations

Notes for models in Table 2 to Table 5: type of function: 1 – linear, 2 – quadratic, 3 – cubic; model parameters: a_{yt}, b_{yt}, c_{yt}, d_{yt}; Correlation index I_{yt} ; * – significance level $\alpha = 0.05$; ** – significance level $\alpha = 0.01$

correlation indices are statistically significant at the significance level $\alpha = 0.01$ or $\alpha = 0.05$. Linear trends in meat production (pigs) are declining in Bulgaria, Czech Republic, Denmark, Greece, France, Croatia, Italy, Latvia, Lithuania, Hungary, Poland, Romania, Slovenia, Finland, Sweden, Slovakia, Cyprus and Malta, see their negative regression coefficients b_{yt}. Increasing linear trends are shown by the remaining member states of the European Union: Belgium, Germany, Estonia, Ireland, Spain, Luxembourg, the Netherlands, Austria, Portugal and the United Kingdom, see their positive regression coefficients b_{yt}.

Conclusions

The article evaluated important aspects of the pork market including correlation matrices of its indicators and key developmental trends in the member states of the European Union. The key pig meat producing countries of the European Union are Germany and Spain. Sharpest rises in pig meat production were recently observed in Netherlands and Spain despite that the average real-terms price of pigs in the EU deeply dropped back down to levels similar to the previous lows in the last decade. The main production area is located between Germany and Belgium and accounts for 30 per cent of pigs. However, there are also other important regions, such as Catalonia and Murcia in Spain, Lombardy in Italy, Brittany in France and some areas of central Poland and northern Croatia.

Pig production is geographically allocated in a number of countries where more than two thirds of pigs are concentrated in Germany, Spain, Denmark, France, the Netherlands and Poland. There are significant structural differences between pig farming in the EU-15 and the new Member States (EU-13). In the EU-13, there are only around three per cent of breeding pigs out of their total number in the EU but there is a high proportion of pigs in small herds. The size of herds in particular countries is also affected by trade in live pigs up to 50 kg, Germany is the main importer of young pigs, with more than a half of the total in the EU, followed by Poland with little bit less than a quarter of the total. Germany and Poland are also the highest importers of breeding and slaughter animals. Denmark is than the main exporter of piglets in the EU (more than a half of the total). Nevertheless, exports

of pigs for slaughter are much more divided between EU member states.

The decline in the number of pigs in some countries can be attributed to low prices and low profitability. The reduction in the number of sows has been greater than expected in the last decade. During this period, there were also high fluctuations in prices of feed, which led to high prices for cereals and compound feed. This caused a very difficult situation, which forced a significant number of pig farmers to stop the production. While large producer countries are increasing their production (Germany, Spain), in a number of traditional EU-13 producer countries there has been a decline in production in the last decade (Romania, Hungary, Czech Republic). However, in Romania the negative trend gradually reversed despite the initial threatening decline (similarly later in Hungary). The only exception among large producers within the EU-13 is Poland, where the decline in production was only slight and a positive growth trend gradually emerged.

The scientific contribution of this article is to be found in the calculation of models of development trends in pork production and correlations of pig breeding and other indicators that is based on an extensive analysis of the pork market in the European Union. The article revealed several correlations of pig breeding and other indicators that were calculated on the basis of relevant indicators from the member states of the European Union. A linear development trend of meat production (pigs) is declining in most countries of the European Union, when in the vast majority of countries the results are statistically highly significant. In other countries the statistical significance increases gradually depending on chosen level of the model and the development of monitored indicator is better expressed by nonlinear development models. Pig production and pork market are an important part of European agribusiness that is highly specialized across borders, such as Denmark for piglet breeding or Spain for fattening. Mixed producers such as Belgium, Denmark, Germany and the Netherlands then form one of the main production areas of this commodity.

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