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Convergence of prices on the pig market in selected European Union countries. Case study

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Abstract: Due to its specificity, animal production depends to a lesser extent than plant production on agrometeorological conditions. Interdependence between the prices of animal products and climatic conditions manifests itself primarily through the fodder markets, which determine the profitability of animal breeding and keeping. The process of economic integration should contribute to a decline in price differentiation between European Union (EU) countries. In the case of the pig market, however, it is necessary to bear in mind the pig cycle, which particularly affects the supply of livestock and their prices. The Common Agricultural Policy (CAP) currently implemented is not adapted to the turbulent global challenges and, underlining the lack of tools adequate to the increasingly frequent and stronger price fluctuations in agricultural markets, consider it necessary to quickly implement a new strategic reformatting of the EU agricultural policy. This study aims to examine the stochastic convergence between prices on the pig market in the EU countries. The research was conducted using, among others, the augmented Dickey-Fuller (ADF) test and the Johansen test. The monthly data from January 2008 (2008M1) to December 2019 (2019M12) were used in this study (Eurostat, Statistical Yearbook of Agriculture). The conducted research indicates the existence of convergence paths between some countries and the group of EU-15 countries.

Keywords: agricultural; economic integration; piglet prices

Economic integration brings changes related to the removal of trade barriers, harmonization of tax systems, increase transparency of prices, reduction of exchange rate risk. In the literature, there are many of its concept, which does not allow for the unambiguous classification. The research on the long-term rate of economic growth and later on economic and social convergence began with Solow's neoclassical growth model (Solow 1956). In general, convergence can be defined as a development process as a result of which economic variables in the analysed countries get closer to each other over time. On the other hand, Nyberg et al. (1983) define convergence as development as a result of which economic variables in the analysed countries come closer together in time. In this approach, the emphasis on reducing regional inequalities between economies stimulates the convergence process.

The theoretical basis for the consideration of price convergence is the law of one price, according to which in conditions of perfect competition the price of the same goods in different countries to equalize, and the only differences are due to transport costs (Samuelson 1952). In fact, the law of a single price is difficult to meet due to imperfect forms of market activity. The ongoing integration processes in the European Union (EU) market should, however, lead to a reduction in price differentiation even in geographically distant markets (Fritzer 2012). Otherwise, the existence of price differences for tradables could be used for profit taking (price arbitrage). The reduction of price dispersion is also sup-

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ported by the growing importance of international trade (Sevela 2006).

The aim of this study is to analyse the price convergence process on the pig market in the EU, in the face of different levels of integration between the individual Member States in 2008–2019. The process of economic integration should contribute to a decline in price differentiation. It was decided to analyse this research area and verify the hypothesis that in the EU market, as a result of achieving successive degrees of integration of agricultural markets, there is convergence, which means that the differentiation of the level of agricultural prices between individual agricultural markets decreases over time, and the relationship between the initial price level and the average rate the price increase is negative. The research used a stochastic approach based on time series, which in turn entails the use of the Johansen test. This method is based on the matrix trace test and the test of the maximum eigenvalue of the matrix, which allows for the analysis of long-term relationships between the examined prices of agricultural products – pigs. The number of cointegrating compounds can be determined on the basis of Johansen's procedure.

MATERIAL AND METHODS

In the literature, there are two approaches presented research based on the convergence of time series, both considering the stochastic nature. Bernard and Durlauf (1996) defined convergence through cointegrated time series, which enforces the same degree of integration of the studied time series. They defined convergence in the country set as follows (Meyer et al. 1975):

$$\lim_{T\to\infty} E\left(\ln y_{i,t+T} - \ln y_{j,t+T} \middle| F_t\right) = 0,\ \forall i,j \in I \tag{1}$$

where: $E(a|b)$ – differences in long-term forecasts of the variable logarithms for country i and country j; $y_{i,\,t\,+\,T}$, $y_{j,\,t\,+\,T}$ – value of variable for countries i and j in the period $t + T$; F_t – a set of information usually composed of various time functions as well as current and delayed variables $\ln y_{i,\,t\,+\,T}$, $\ln y_{j,\,t\,+\,T}$.

According to the above, the phenomenon of convergence does not occur when the conditional differences $\ln y_{i,\,t\,+\,T} - \ln y_{j,\,t\,+\,T}$ are characterized by stochastic or deterministic trends. According to this approach, it is possible to verify the hypothesis that the difference in variables between two economies is narrowing by means of unit root tests (Glynn et al. 2007).

In the second approach, represented by Evans and Karras (1996), the level of the value of the studied variable of a given country is associated with the average level of the variable value in the studied sample or with the highest value of this variable. In this approach, the convergence of the deviations in time between the value of the studied variable for a given country and the average value of this variable in the group of countries studied to a certain level is required. When this level is equal to zero, then there is absolute convergence, while when it is different from zero, there is conditional convergence. According to these authors, convergence takes place in the group of countries under study, if for all and the following condition is met:

$$\lim_{T\to\infty} E_t\left(\ln y_{i,t+T} - \ln \overline{y}_{t+T}\right) = \mu_i \tag{2}$$

where: $\overline{y}_{t+T}$ – average value of variable in the sample for the period $t + T$; μ_i – constant.

The verification of convergence hypotheses in both approaches requires that the considered time series are stationary. Among the many tests for the existence of the unit root in the work, the augmented Dickey-Fuller (ADF) test was used (Kwiatkowski and Schmidt 1990). This test assumes in the null hypothesis that the examined time series is non-stationary due to the presence of a unit root (H_0: $\delta = 0$). The alternative hypothesis assumes the stationarity of the time series (H_1: $\delta < 0$). A modified version of the ADF test is often used and it is given as follows (Rutkowska and Ptak 2012):

$$\begin{aligned}\Delta y_t &= \mu + \delta y_{t-1} + \sum_{i=1}^{k} \delta \Delta y_{t-i} + e_t \text{ lub } \Delta y_t = \\ &= \delta y_{t-1} + \sum_{i=1}^{k} \delta_i \Delta y_{t-i} + e_t\end{aligned} \tag{3}$$

where: Δ – first difference operator; μ – constant; δ – unit root; e_t – random component.

The decision about rejection or not, the null hypothesis is made on the basis of the Dickey-Fuller (DF) statistics calculated using the quotient:

$$DF = \frac{\hat{\delta}}{S\left(\hat{\delta}\right)} \tag{4}$$

where: $\hat{\delta}$ – estimated parameter of δ; $S\left(\hat{\delta}\right)$ – standard error of that estimate.

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The choice of lags k in the ADF test was made arbitrarily, taking into account the cyclical nature of agricultural production (pig cycle).

If there is a long-term relationship between the non-stationary time series and the deviations from this long-term path are stationary, the time series are considered to be cointegrated.

A common definition of cointegration is the definition of Engle and Granger, which says that x_t and y_t time series are called cointegrated x_t, y_t ~ CI (d, b) of the d, b ($d \geq b \geq 0$) order, if (Engle and Granger 1987; Maddala and Kim 1998):

i) Both time series are integrated in order $d(x_t y_t \sim \mathrm{I}(d))$;

ii) There is a linear combination of these variables, i.e. $\beta_1 x_t + \beta_2 y_t$, which is integrated on the order $d \sim b$.

The original Engle and Granger's concept has been extended in various ways including the seasonal cointegration concepts (Kunst and Franses 1998; Franses and Kunst 1999; Darne 2004) and multivariate (Johansen and Juselius 1992). Noteworthy is Johansen's procedure, which is the first to investigate the number of cointegrating vectors in vector autoregression (VAR) models. Johansen's test is based on the character model (Gordon 1995; Dwyer 2015):

$$\Delta Z_t = \alpha_1 \Delta Z_{t-1} + \alpha_2 \Delta Z_{t-2} + \ldots + \alpha_k \Delta Z_{t-k} + e_t \qquad (5)$$

where: Z_t – expounded processes.

for N processes expounded, which means that N is estimated separate regression equations.

After estimating the parameters of the regression models and then determining the roots of the characteristic equation, the statistics of one of the two Johansen tests are calculated (Johansen 1988; Lütkepohl et al. 2000; Hjalmarsson and Österholm 2007):

– trace test: $$\lambda_{trace}\left(r\right) = -T \sum_{i=r+1}^{N} \ln\left(1 - \lambda_i\right) \qquad (6)$$

– maximum eigenvalue test:

$$\lambda_{max}\left(r, r+1\right) = -T \ln\left(1 - \lambda_{r+1}\right) \qquad (7)$$

where: λ_i – estimated eigenvalues; T – number of observations; N – number of regions; r – index of the sum self-explanatory.

The trace test statistic is used to test the null hypothesis that consists the number of dissimilar cointegrating vectors is less than or equal to r. The alternative hypothesis consists that this number is greater than r. The maximum eigenvalue test statistic is used to validate the null hypothesis that of the cointegrating vectors is r, against the alternative assuming that they are $r + 1$.

The subject of the empirical study is the monthly time series of pig prices in selected EU countries from January 2008 (2008M1) to December 2019 (2019M12), provided by Eurostat (2020). To study the convergence between piglet prices in EUR/100 kg countries were selected, the author divided them into five groups, and a reference group is a group of 15 EU countries. The division was suggested by the work of Kluth (2016). The individual groups are as follows:

Group I: EU Member States from the former communist bloc that joined the EU structures in 2004: Czech Republic, Estonia, Lithuania, Latvia, Poland, Slovakia, Slovenia, Hungary, also including Bulgaria and Romania, that joined in 2007, and Croatia, that joined in 2013.

Group II: Central and Eastern European countries that are in the EU but have not joined the Eurozone: Bulgaria, Croatia, the Czech Republic, Poland, Romania and Hungary.

Group III: Central and Eastern European countries that joined the EU in 2004 and are already in the Eurozone: Estonia, Lithuania, Latvia, Slovakia and Slovenia.

Group IV: Countries that belong to the 'old' EU-15 but are considered the least developed: Greece, Spain, Portugal and Italy.

Group V: Countries which formed the core of the EU: Austria, France, Germany and United Kingdom.

RESULTS AND DISCUSSION

The basis of the study were piglet prices in EUR/100 kg, Figures 1–5 show the development of the level of these prices for the series of selected groups of EU countries and the EU-15 in 2008M1–2019M12.

In Figures 1–5 the time series are presented, the increasing tendency in the price level of piglets in EUR/100 kg is visible in 2008–2014. Since 2014, the pig market has collapsed, which resulted from the increase in pig production in almost all EU countries. In the first half of 2015, the largest increase in the production of this type of meat was recorded in Spain (+9.1%), Denmark, Germany, the Netherlands, Poland, Belgium, France and the United Kingdom. The increase in production, low prices, the fall in the value of the euro and strong demand from Asia contributed to the increase in pork exports from EU countries, in the first seven months of 2015 by 6.6%. It should also be mentioned that the growing pig production in Rus-

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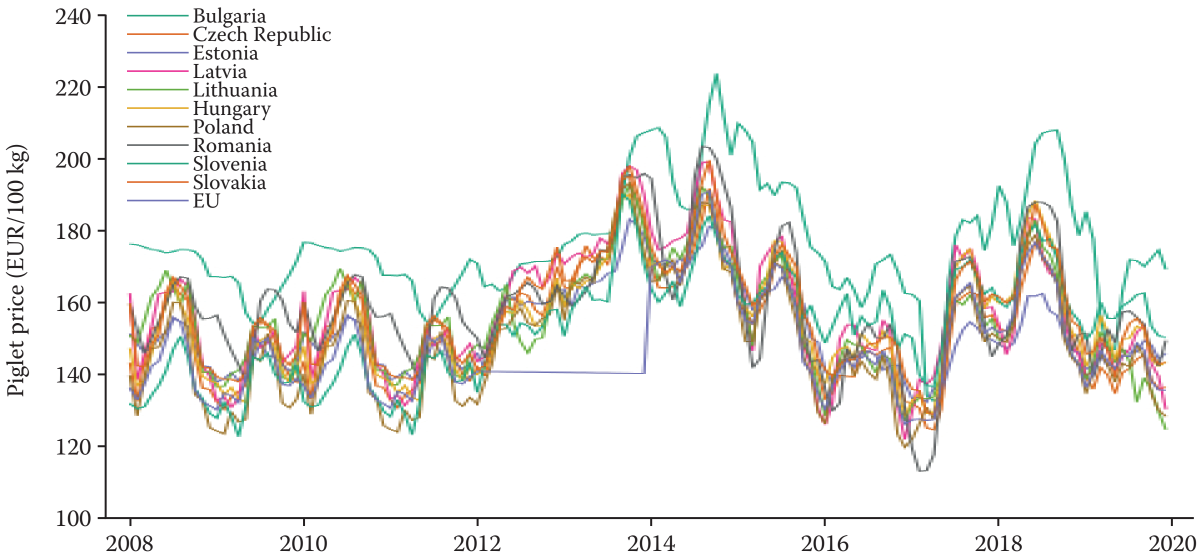

Figure 1. Piglet prices – Group I from 2008M1 to 2019M12 (EUR/100 kg)

Source: Own calculations based on Eurostat (2020) database

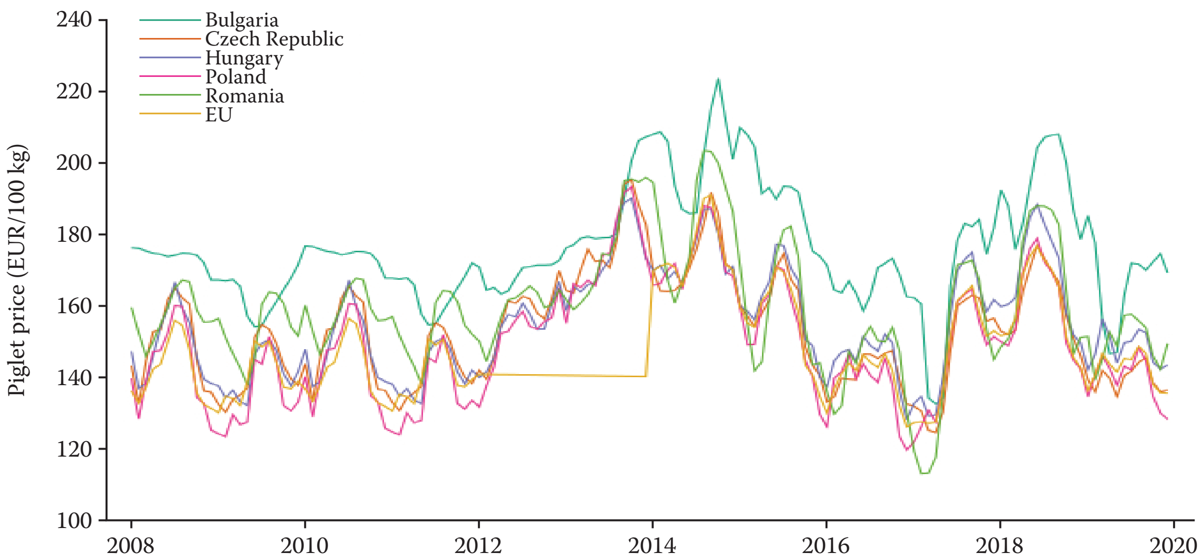

Figure 2. Piglet prices – Group II from 2008M1 to 2019M12 (EUR/100 kg)

Source: Own calculations based on Eurostat (2020) database

sia and the unstable economic situation in that country, even after the lifting of the embargo, did not trigger exports in this direction by EU countries. Bearing in mind the cyclical nature of pig production, the situation from 2014–2015 repeated itself in 2018. Then, the large supply of pork, both in the EU and on the global market, resulted in the prices of live pigs in the EU countries being below the 2017 level.

Before the study of the degree of integration of time series and the occurrence of cointegration, a hypothesis was made about the existence of price convergence. Therefore, the expected results concern the stationarity of single time series or, in the absence of stationarity, the occurrence of cointegration in the group of the series under study. Integration analysis was performed using the ADF test. The study of the number of cointegrating vectors was carried out using the Johansen test. The results of the stochastic convergence study for piglet prices in EUR/100 kg are shown in Tables 1, 2.

The results of testing the stationarity of time series – piglet prices in EU countries and the EU-15 indicate that for fourteen countries and the EU-15 the unit root

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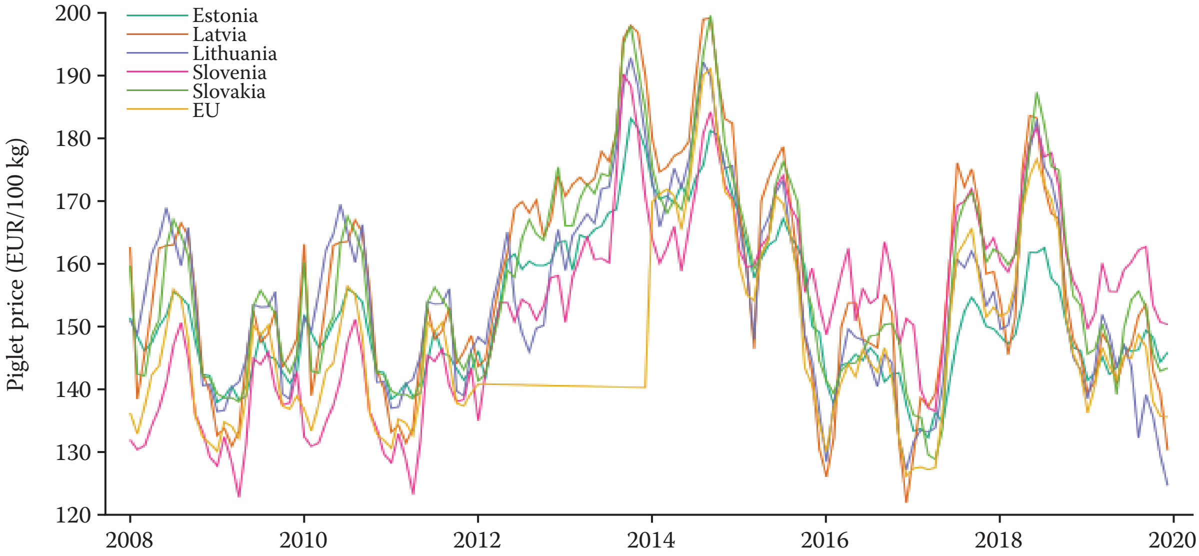

Figure 3. Piglet prices – Group III from 2008M1 to 2019M12 (EUR/100 kg)

Source: Own calculations based on Eurostat (2020) database

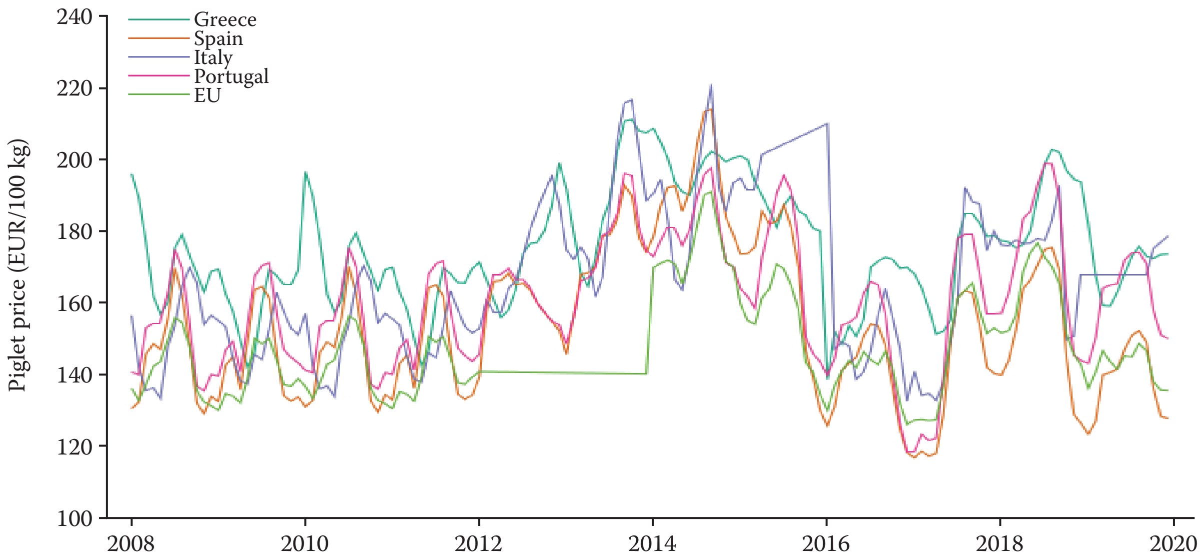

Figure 4. Piglet prices – Group IV from 2008M1 to 2019M12 (EUR/100 kg)

Source: Own calculations based on Eurostat (2020) database

does not occur, and thus these series are stationary. For the remaining countries: Czech Republic, Denmark, Estonia, Spain, France, Lithuania, Romania, the unit root was found.

At the same time, the first differences for these time series are stationary (Table 1). The stationarity of the time series of piglet prices (EUR/100 kg) may indicate the existence of absolute convergence according to Evans and Karras (1996). This means that the price level of piglets is determined by own long-term tendency to reduce the distance to the initial state.

On the other hand, the occurrence of the unit root testifies to the lack of absolute β-convergence in the studied countries. Conducting a cointegration study will allow verifying the hypothesis of stochastic convergence in the studied groups of countries. The results of cointegration testing with Johansen's tests are presented in Table 2.

Table 2 where the statistics on the piglet cointegration survey for five groups of the EU Member States and individual countries considered individually with the EU-15 are presented, shows that for most countries the phenomenon of stochastic convergence does

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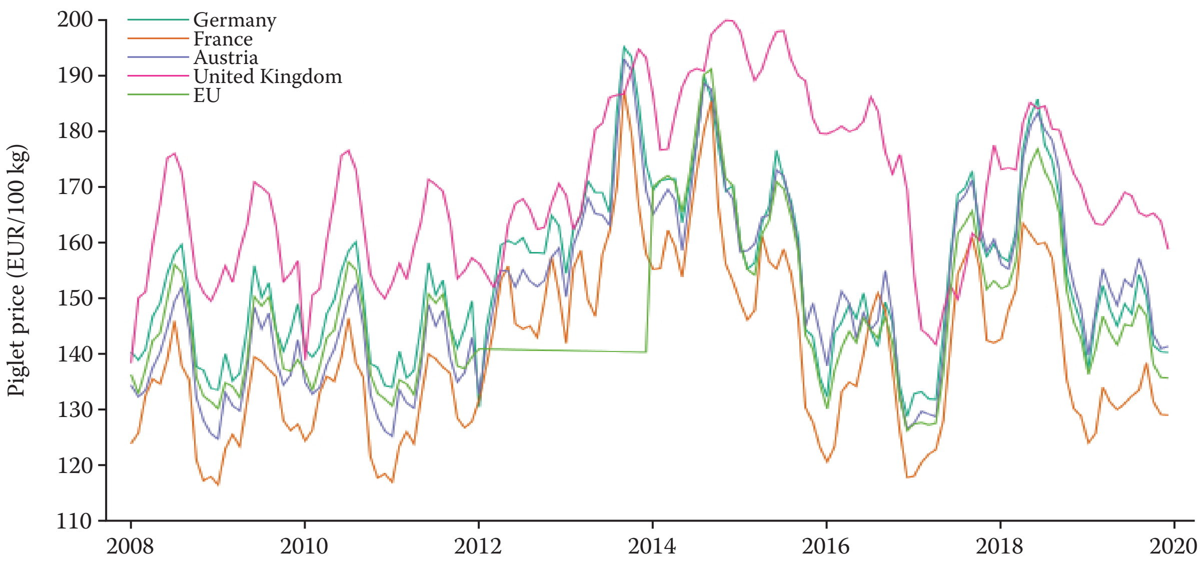

Figure 5. Piglet prices – Group V from 2008M1 to 2019M12 (EUR/100 kg)

Source: Own calculations based on Eurostat (2020) database

not occur, as it is not confirmed by the Johansen cointegration test. Based on the results (Table 2), it can be concluded that there is cointegration between the countries of the Group II: Bulgaria, Croatia, the Czech Republic, Poland, Romania, Hungary and the EU-15, as well as the Group V: Austria, France, Germany and the United Kingdom, and the EU-15. In the case of both groups, the number of cointegrating vectors is equal to the number of the tested time series, which means the presence of stationarity in the series under study and, according to the definition of Evans and Karras (1996), we can speak of absolute convergence.

Moreover, the results of the study of the cointegration process for the Groups I and IV indicate the lack of convergence between these countries and the EU, which at the same time proves the lack of stochastic convergence. Moreover, in the cointegration study of each time series separately with the time series representing piglet prices in EUR/100 kg EU-15, absolute cointegration was found.

CONCLUSION

Summarizing the results of research on the integration and cointegration of the studied time series for individual countries in the years 2008–2019, the following conclusions can be drawn:

i) The Group I has five paths of convergence with the EU-15, while the Group IV has two such paths;

ii) For the countries of Groups II and V and the EU-15, there is absolute convergence in terms of the price

Table 1. Unit root test results for the analysed time series in 2008M1–2019M12

Country	ADF test results	
	H_0: I(1)	H_0: I(2)
Belgium	**–3.316 (0.014)**	–6.609 (0.000)
Bulgaria	**–3.116 (0.025)**	–6.201 (0.000)
Czech Republic	–2.368 (0.150)	**–7.302 (0.000)**
Denmark	–2.531 (0.107)	**–6.514 (0.000)**
Germany	**–3.730 (0.003)**	–7.131 (0.000)
Estonia	–1.511 (0.528)	**–6.604 (0.000)**
Greece	**–3.032 (0.032)**	–6.445 (0.000)
Spain	–2.729 (0.069)	**–7.373 (0.000)**
France	–2.523 (0.109)	**–7.466 (0.000)**
Italy	**–3.636 (0.005)**	–10.473 (0.000)
Latvia	**–3.911 (0.001)**	–7.140 (0.000)
Lithuania	–2.422 (0.135)	**–6.940 (0.000)**
Hungary	**–4.026 (0.001)**	–6.891 (0.000)
Netherlands	**–3.580 (0.006)**	–6.880 (0.000)
Austria	**–3.778 (0.003)**	–6.987 (0.000)
Poland	**–3.626 (0.005)**	–6.867 (0.000)
Portugal	**–3.695 (0.004)**	–7.721 (0.000)
Romania	–2.479 (0.120)	**–7.962 (0.000)**
Slovenia	**–3.456 (0.009)**	–7.213 (0.000)
Slovakia	**–4.089 (0.001)**	–6.768 (0.000)
United Kingdom	**–3.123 (0.024)**	–7.271 (0.000)
EU-15	**–4.006 (0.001)**	–7.090 (0.000)

ADF – augmented Dickey-Fuller; statistics values for which the null hypothesis (H_0) was rejected are marked in bold; I(1), I(2) – first- and second-order integrated process, respectively
Source: Own calculations based on Eurostat (2020) database

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Table 2. Johansen test results for piglet prices in groups of countries in 2008M1–2019M12 (EUR/100 kg)

Degree of cointegration	Eigenvalues	Trace test	*P*-value for λ_{tr}	Test statistics λ_{max}	*P*-value for λ_{max}
Group I					
0	0.393	261.990	**0.000**	68.864	0.000
1	0.356	193.130	**0.000**	60.709	0.000
2	0.309	132.420	**0.000**	50.913	0.001
3	0.210	81.506	**0.004**	32.586	0.068
4	0.162	48.921	**0.038**	24.412	0.122
5	0.103	24.508	0.186	15.060	0.297
6	0.053	9.448	0.332	7.507	0.440
7	0.014	1.941	0.164	1.941	0.164
Group I and EU-15					
0	0.442	334.340	**0.000**	80.396	0.000
1	0.410	253.950	**0.000**	72.756	0.000
2	0.331	181.190	**0.000**	55.380	0.002
3	0.311	125.810	**0.000**	51.405	0.001
4	0.205	74.405	**0.019**	31.656	0.088
5	0.115	42.749	0.139	16.908	0.597
6	0.093	25.840	0.137	13.453	0.426
7	0.069	12.388	0.140	9.917	0.222
8	0.018	2.471	0.116	2.471	0.116
Group II					
0	0.259	122.150	**0.000**	41.411	0.003
1	0.224	80.735	**0.000**	35.008	0.003
2	0.155	45.728	**0.000**	23.220	0.023
3	0.117	22.508	**0.003**	17.168	0.015
4	0.038	5.340	**0.021**	5.340	0.021
Group II and EU-15					
0	0.335	170.770	**0.000**	56.329	0.000
1	0.266	114.440	**0.000**	42.724	0.002
2	0.214	71.714	**0.000**	33.272	0.006
3	0.125	38.443	**0.003**	18.355	0.120
4	0.094	20.088	**0.008**	13.540	0.063
5	0.046	6.548	**0.011**	6.548	0.011
Group III					
0	0.298	104.160	**0.000**	48.880	0.000
1	0.179	55.280	**0.008**	27.184	0.053
2	0.112	28.097	0.079	16.420	0.209
3	0.066	11.677	0.175	9.453	0.256
4	0.016	2.224	0.136	2.224	0.136
Group III and EU-15					
0	0.430	230.170	**0.000**	74.098	0.000
1	0.315	156.080	**0.000**	49.987	0.000
2	0.272	106.090	**0.000**	41.883	0.000
3	0.233	64.205	**0.000**	35.090	0.000
4	0.148	29.115	**0.000**	21.174	0.003
5	0.058	7.941	**0.005**	7.941	0.005

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Table 2. To be continued

Degree of cointegration	Eigenvalues	Trace test	P-value for λ_{tr}	Test statistics λ_{max}	P-value for λ_{max}
Group IV					
0	0.243	71.917	**0.000**	38.441	0.001
1	0.130	33.476	**0.017**	19.188	0.092
2	0.078	14.288	0.074	11.207	0.146
3	0.022	3.081	0.079	3.081	0.079
Group IV and EU-15					
0	0.300	102.310	**0.000**	49.133	0.000
1	0.158	53.181	**0.013**	23.668	0.149
2	0.110	29.513	0.054	16.038	0.232
3	0.073	13.475	0.098	10.383	0.191
4	0.022	3.092	0.079	3.092	0.079
Group V					
0	0.227	82.767	**0.000**	35.477	0.003
1	0.141	47.291	**0.000**	20.925	0.052
2	0.102	26.366	**0.001**	14.909	0.037
3	0.080	11.457	**0.001**	11.457	0.001
Group V and EU-15					
0	0.324	118.890	**0.000**	54.013	0.000
1	0.170	64.875	**0.000**	25.785	0.082
2	0.109	39.090	**0.003**	15.990	0.235
3	0.088	23.099	**0.002**	12.730	0.085
4	0.072	10.369	**0.001**	10.369	0.001

Statistics values for which the null hypothesis (H_0) was rejected are marked in bold
Source: Own calculations based on Eurostat (2020) database

level of piglets (EUR/100 kg), which means that the prices are levelling in relation to the average price of the EU-15;

iii) The countries of Group III and the EU-15 have significant co-integrating vectors, which may indicate mutual trade ties between countries and their changes as a result of the processes resulting from the Common Agricultural Policy (CAP);

iv) By analysing the results for individual countries, the presence of stochastic convergence was identified.

The obtained results of the integration and cointegration study allowed showing the relation of piglet prices (EUR/100 kg) between the EU countries. At the same time, it should be noted that this work does not fully cover the subject. In the next step, the research should be extended to 2020–2021 and check whether: *i*) the appearance of COVID-19 had an impact on the price level on the agricultural market, *ii*) COVID-19 had an impact on the relationship between prices in different countries, *iii*) or COVID-19 has lowered the demand for some food products, mainly due to restrictions in the agri-food sector.

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