MODELLING AGRICULTURAL COMPETITIVENESS SENSITIVITY TO FACTOR PRICE FLUCTUATIONS IN THE EU

Astra Auzina-Emsina[1], Alberts Auzins[2], Armands Veveris[2], Andris Lismanis[3]
[1]Riga Technical University, Latvia;
[2]Institute of Agricultural Resources and Economics, Latvia; [3]Edo Consult, Ltd., Latvia
astra.auzina-emsina@rtu.lv, alberts.auzins@arei.lv, armands.veveris@arei.lv, lismanis@edo.lv

Abstract. As the European agricultural sector faces increasing exposure to global market volatility and geopolitical disruptions, assessment of the sensitivity of farm competitiveness to price shocks has become essential for rural policy. This research presents an econometric modelling and simulation framework designed to quantify the economic resilience of agricultural holdings across the European Union (EU-27). The study employs a log-log regression analysis to estimate the elasticity of the Output-Input (*OI*) ratio (primary indicator of competitiveness) against fluctuations in output prices and production factor costs, such as energy, fertilizers, and feed. The methodology is centred on the development and testing of sector-specific regression models. By utilizing longitudinal data from the Farm Accountancy Data Network (2014-2023), the research simulates how price changes affect through different farming specializations, with a focus on crop, dairy, and granivore farming sectors. A key feature of the study is the comparative analysis between the EU-27 average and the Baltic region, particularly Latvia, which serves as a case study for high-sensitivity markets. Modelling results demonstrate considerable variation in sensitivity patterns across member states. For instance, the Latvian crop sector exhibits 12% lower sensitivity to fluctuations in wheat prices and 54% higher sensitivity to fluctuations in urea prices compared with the EU-27. The findings argue that regions considered "price-takers" are more vulnerable to losing their competitiveness with input costs inflation. The paper concludes that this modelling approach provides a vital diagnostic tool for simulating the impact of future market shocks, supporting the development of adaptive and targeted solutions and resource-efficient management strategies to stabilize the agricultural conditions and policy in the EU.

Keywords: economic simulation, price elasticity, agricultural competitiveness, log-log regression, *OI* ratio, factor price volatility.

Introduction

Global market volatility and geopolitical disruptions are posing major challenges and risks to the European agricultural sector in diverse ways, affecting the competitiveness and market positions of individual farms, agricultural branches, and the EU agricultural sector as a whole. Hence, assessing the sensitivity of farm competitiveness to price shocks has become essential for rural policy. Field crop farming heavily depends on prices and fertilizers, including nitrogen (urea), and there is a considerable disparity between individual EU member countries concerning the amounts of applied nitrogen fertilizer and the usage efficacy [1]. Wheat farming is losing its importance in some EU countries, as Poland, in terms of agricultural revenue generation [2]. Dairy farms face high volatility of milk and dairy product prices [3], however in the long run, milk production in the EU is affected by the size of the economy, private consumption and population [4]. The EU dairy farming is heterogeneous and diverse and there are notable disparities in the distribution of milk costs and prices among member states [5]. Granivore farms (pig and poultry) and field crop farms have higher risk resilience, remaining robust or adaptable [6].

Various studies are examining the overall agricultural disparities amid the EU countries. Identified notable differences explain the diverse development paths within the EU [7]. There are identified distinct agricultural models, as five clusters reflecting diverse transitions: Eastern European countries increasingly moved toward mixed farming (as Latvia, Lithuania, and Hungary) or large-scale commercial farming (as the Czech Republic, Estonia, and Slovakia), subsistence and small-scale farming (Bulgaria and Romania), and Western and Northern countries sustained high levels of modernization, additionally Ireland progressing and the Netherlands standing out as a distinct high-tech agricultural model [8]. However, the number of large-sized farms is growing in Latvia. Latvian agricultural farms, industrial food producers and consumers are mostly price takers, and hence the changes in the global price level principally determine the price level in the local market [9]. Agricultural performance and revenues affect rural development, requiring tailored policies.

The aim of the study is to quantify the economic resilience of agricultural holdings across the European Union (EU-27) by applying econometric modelling and a simulation framework. The study employs a log-log regression analysis to estimate the elasticity of the agricultural Output-Input (*OI*) ratio (primary indicator of competitiveness) against fluctuations in output prices and production factor costs, such as energy, fertilisers, and feed.

The challenges and opportunities for Latvia's agricultural sector concerning further EU enlargement and additional price and production performance effects are examined in more details revealing various aspects and affected areas [10]. The current study is part of this wider examination.

Materials and methods

The study relies on the longitudinal data from the Farm Accountancy Data Network (FADN) (2014–2023) [11], the research simulates how price changes affect through different farming specializations, with a focus on field crop, dairy, and granivore (pigs and poultry) farming sectors. The FADN data set is widely applicable, as covering core dimensions: income and productivity, asset base, land size, and labour structure [12]; examining sustainable intensification based on resource productivity [13]; identifying clusters in agricultural models [14], focusing on certain agricultural activities as dairy farms grouping into types based on production potential [15]. Due to data unavailability in the European FADN database for granivore holdings in Latvia the Latvian Farm Accountancy Data Network (SUDAT) [16] database is used. Furthermore, Indexmundi.com [17] and Agri-food data portal databases [18] are used for price data.

Two indicators have been used to characterize and analyze the production efficiency of farms in Latvia and the EU: Total output to total input ratio (*OI*) – calculated based on FADN data on total farm output (indicator SE131) and total input (SE270) and Ratio of total output and support (subsidies) to total inputs – calculated based on FADN data according to the following formula:

$$OI_S = \frac{O + S_{CO} + S_{inv}}{I}, \quad (1)$$

where OI_S – ratio of total output and support (subsidies) to total costs;
O – total output;
S_{co}– total subsidies excluding on investments (SE605);
S_{inv} – subsidies on investments (SE406);
I – total inputs.

It should be noted that the indicator *OI* (SE132) is also collected in the FADN database. However, in order to eliminate the effect of rounding on the analysis results, this indicator has been calculated directly in the study. This indicator characterizes the ability of agricultural holdings to cover their operating costs (including depreciation and external costs) from operating revenues and does not take into account the impact of support (subsidies) [19]. Thus, a value of the indicator lower than 1 indicates that agricultural holdings are unable to cover their costs without support. The indicator OI_S is an additional indicator created by the authors of the study, which characterizes the ability of agricultural holdings to cover their operating costs, also taking into account the impact of subsidies (including investments). At the same time, both of the aforementioned indicators also characterize the profitability and competitiveness of farms.

In order to assess the sensitivity of farms to changes in the prices of output and production factors, a regression analysis has been performed using the log-log regression model. This model has assessed the sensitivity of *OI* (dependent variable) to (elasticity depending on) changes in factors (output prices, production factor prices). The following regression model has been used for the regression analysis of the field crop farming specialization:

$$\ln\left(Y_{OI\_f}\right) = c_0 + c_1 \cdot \ln\left(P_{wh}\right) + c_2 \cdot \ln\left(P_{ur-1}\right), \quad (2)$$

where Y_{IO_f} – *OI* for field crop farming specialization;
c_0 – intercept (constant);
c_1 – regression coefficient for the first factor;
P_{wh} – wheat price (data from Indexmundi.com);
c_2 – regression coefficient for the second factor;
$P_{ur\text{-}1}$ – urea price in the previous year (Indexmundi.com data).

A regression analysis has been performed for the dairy farming specialization using the following equation:

$$\ln\left(Y_{OI\_m}\right) = c_0 + c_1 \cdot \ln\left(P_{rm}\right) + c_2 \cdot \ln\left(P_{wh}\right) + c_3 \cdot \ln\left(P_{ur}\right), \quad (3)$$

where Y_{IO_f} – *OI* for dairy farming specialization;
c_0 – intercept;
c_1 – regression coefficient for the first factor;
P_{rm} – purchase price of raw milk (data from the Agri-food data portal)
c_2 – regression coefficient for the second factor;
P_{wh} – wheat price (Indexmundi.com data);
c_3 – regression coefficient for the third factor;
P_{ur} – urea price in the current year (Indexmundi.com data).

It should be noted that the granivores specialization, including pig farming and poultry farming, is a very specific direction, as there are differences between these two types of livestock farming and the proportions between pig farming and poultry farming differ amid countries. Therefore, it is difficult to identify factors that sufficiently characterize such a heterogeneous specialization direction. Based on the results of testing various regression models, a regression analysis has been performed for the specialization direction of granivores farming using the following equation:

$$\ln\left(Y_{OI\_g}\right) = c_0 + c_1 \cdot \ln\left(P_{pk}\right) + c_2 \cdot \ln\left(P_{py}\right) + c_3 \cdot \ln\left(P_{sm}\right) + c_4 \cdot \ln\left(P_{wh}\right), \quad (4)$$

where Y_{IO_g} – *OI* for granivores farming specialization;
c_0 – intercept;
c_1– regression coefficient for the first factor;
P_{pk} – pork (grade S) price (data from the Agri-food data portal);
c_2 – regression coefficient for the second factor;
P_{py} – poultry price (data from the Agri-food data portal)
c_3 – regression coefficient for the third factor;
P_{sm} – price of soybean meal (data from Indexmundi.com);
c_4 – regression coefficient for the fourth factor;
P_{wh} – wheat price (data from Indexmundi.com data).

A key feature of the study is the comparative analysis between the EU-27 average and the Baltic region, particularly Latvia, which serves as a case study for high-sensitivity markets.

Results and discussion

Production efficiency indicators for agriculture overall (for all farm specializations) are presented in Fig. 1. In Latvia, the average ratio of total output to total inputs (Output-Input (*OI*) ratio) is lower than 1 (0.950). It is by 16.7% lower than the EU average and is the seventh lowest value among EU Member States. It should be noted that *OI* in Estonia is lower than in Latvia, but in Lithuania it is higher. When assessed by the Output-Input ratio, taking into account support, OI_s in Latvia it is still by 8.7% under the EU average. In all EU Member States, this ratio is higher than 1. Nevertheless, it is relatively low in Latvia, only eight Member States have values lower.

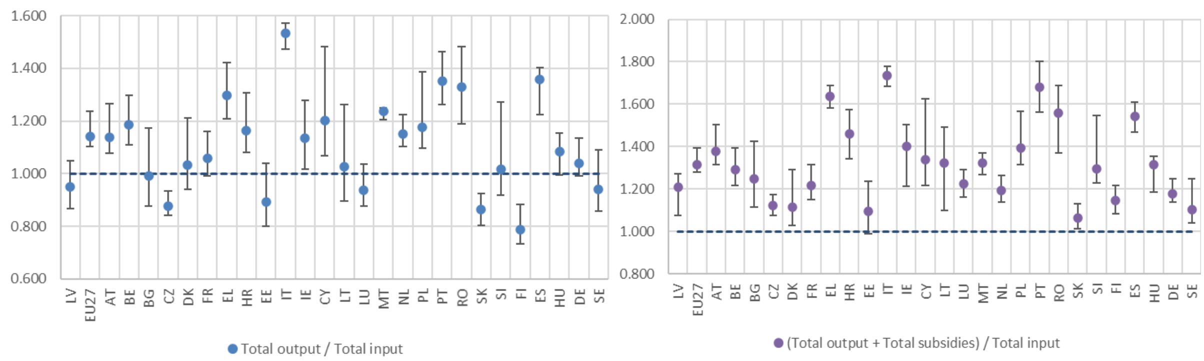

Fig. 1. **Production efficiency in agriculture overall in 2014-2023 in EU countries**

Considering that the most important specialization directions in Latvia are field crops, dairy farming and granivore farming, these three specialization directions have been analyzed in depth. Production efficiency indicators for field crop farms are presented in Fig. 2. In Latvia, the output-input ratio in field crop farms is by 13.3% lower than the EU average, without taking into account the impact of support, and by 9.8% lower, taking into account the impact of support. The average *OI* is lower than in Latvia only in five Member States (including Estonia) and the OI_s is lower in seven Member States (including Estonia). It should be noted that in Lithuania, the average values of these two indicators are higher than in Latvia.

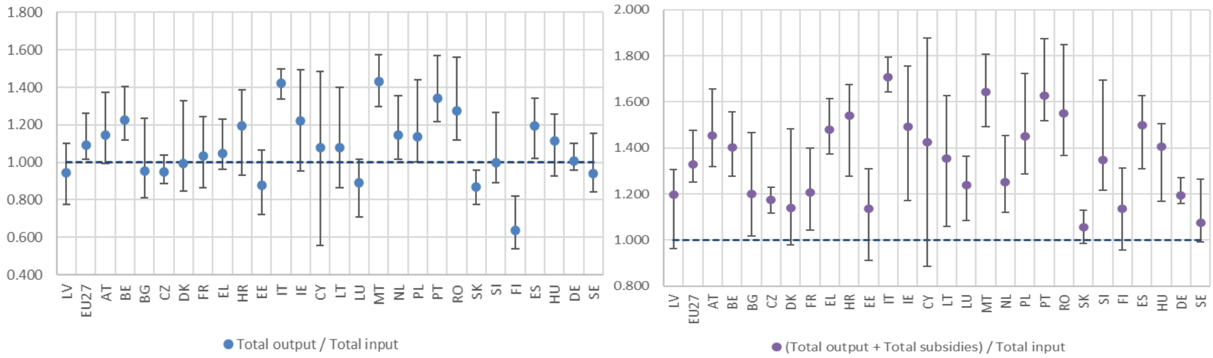

Fig. 2. **Production efficiency in field crop holdings 2014-2023 in the EU countries**

The efficiency indicators of dairy farming are presented in Fig. 3. In Latvia, the output-input ratio is by 17.4% lower than the EU average, and only four other Member States (including Estonia) have an even lower value for this indicator. In turn, taking into account the impact of support, in Latvia this ratio is only by 4.4% lower than the EU average, and lower values for the indicator are found in eleven Member States (including Estonia). In Lithuania, the values of both indicators are higher than in Latvia.

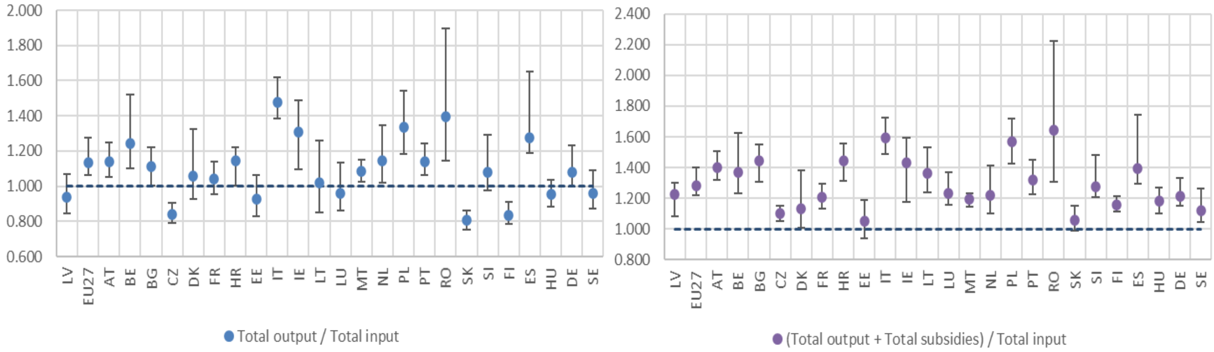

Fig. 3. **Production efficiency in dairy holdings 2014-2023 in the EU countries 1**

Production efficiency indicators in granivore holdings are presented in Fig.

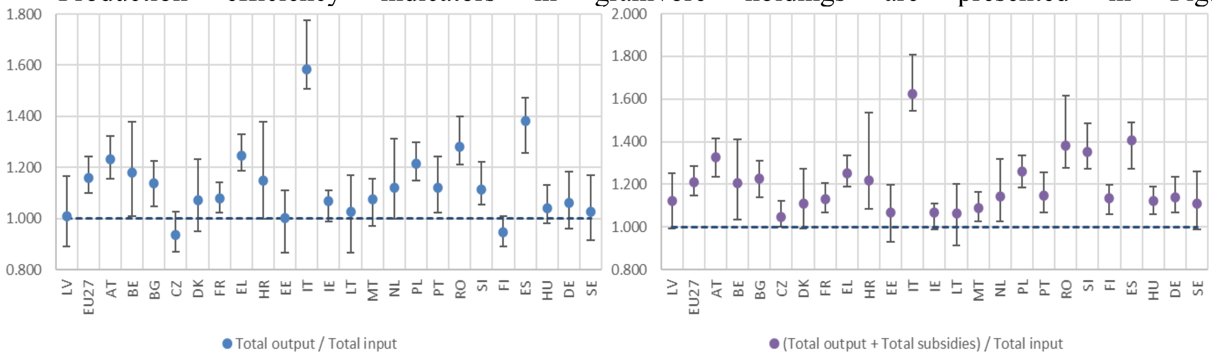

Fig. 4. . It should be noted that there is less data availability for this specialization direction in FADN, e.g., data for the period 2014-2023 are not fully available for several countries (Cyprus, Luxembourg, Slovakia), and data for individual years are missing for some countries (Greece, Lithuania, Ireland, Malta) [10]. For Latvia, data from the national FADN database (SUDAT) have been used, as Latvian data were not published in the EU FADN database. Unlike the previous two specialization

directions, the average Output-Input ratio in Latvia has been slightly above 1 (1.008). However, this indicator is by 13.3% lower than the EU average. It has been even lower only in three Member States (including Estonia). The OI_s indicator in Latvia is by 7.7% lower than the EU average, which is the eighth lowest value. It should be noted that, similarly to the case of the two above-mentioned specializations, the average values of OI and OI_s are higher in Lithuania than in Latvia. These results are comparable to those obtained by analyzing the field crop and dairy farming of Latvia and Lithuania in the previous period [20]. Political initiatives to promote the growing of protein crops locally exist in the EU, however, the results argue that locally grown protein (as soya) is more expensive increasing producing costs [21].

Summarizing, the results argue that compared to both the EU average and other EU Member States, Latvia has a relatively low profitability of agricultural holdings and a high dependence on support (subsidies). This indicates potential competitiveness challenges if support conditions deteriorate in the future or if product and production factor prices change unfavourably.

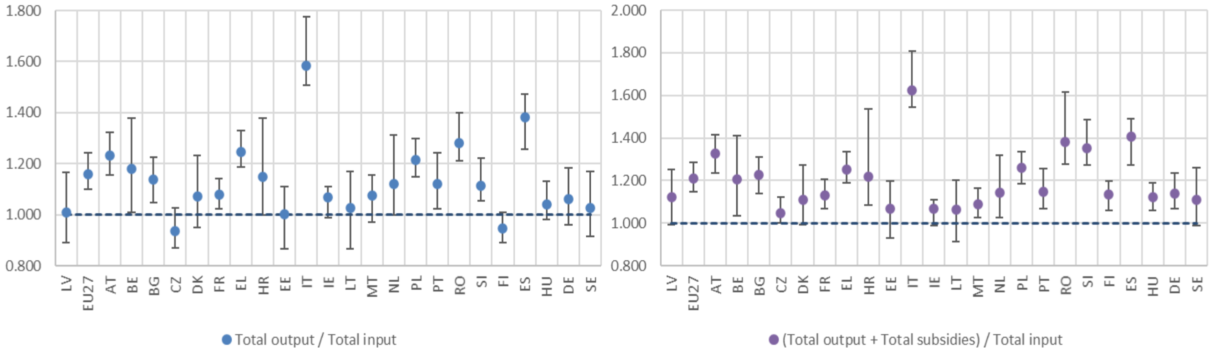

Fig. 4. **Production efficiency in granivore holdings 2014-2023 in the EU countries**

In model (2), two factors are used (wheat price and urea price in the previous year (one period lagged)). In this model, the price of wheat can be largely considered as a proxy for the price of cereals and urea price – a proxy for fertilizers (especially all types of nitrogen fertilizers). The results of the regression analysis for agriculture are presented in Table 1. It should be noted that some countries have inappropriate values of the regression coefficients – negative c_1 values (Luxembourg and Portugal) or/and positive c_2 values (Italy, Cyprus, the Netherlands, Portugal and Germany). Such results can be explained by the fact that in these countries some other specific factors have a significant impact on OI, which are not taken into account by the applied regression model. For this reason, the results are not interpretable for these countries.

Table 1

Regression analysis results for field crop holdings in the EU

Country	c_1	c_2	R^2	DW
Latvia (LV)	0.267	-0.232	0.408	2.306
EU 27 Member States (EU27)	0.304	-0.151	0.948	2.421
Austria (AT)	0.239	-0.051	0.657	2.326
Belgium (BE)	0.279	-0.080	0.827	2.156
Bulgaria (BG)	0.585	-0.383	0.890	2.508
Czech Republic (CZ)	0.143	-0.008	0.861	1.687
Denmark (DK)	0.514	-0.237	0.802	2.535
France (FR)	0.451	-0.230	0.945	2.299
Greece (EL)	0.296	-0.101	0.841	2.085
Croatia (HR)	0.299	-0.304	0.660	2.070
Estonia (EE)	0.393	-0.295	0.607	2.855
Italy (IT)	0.087	0.015*	0.617	1.772
Ireland (IE)	0.580	-0.482	0.933	1.989
Cyprus (CY)	0.184	0.105*	0.506	2.396
Lithuania (LT)	0.527	-0.351	0.557	2.516
Luxembourg (LU)	-0.039*	-0.221	0.936	3.245
Netherlands* (NL)	0.119	0.097	0.730	2.010

Country	c_1	c_2	R^2	DW
Poland (PL)	0.514	-0.290	0.898	1.992
Portugal (PT)	-0.061*	0.155*	0.530	1.407
Romania (RO)	0.345	-0.244	0.590	2.551
Slovakia (SK)	0.164	-0.014	0.430	2.652
Slovenia (SI)	0.255	-0.046	0.563	2.090
Finland (FI)	0.448	-0.304	0.720	2.326
Spain (EU)	0.169	-0.181	0.618	2.925
Hungary (HU)	0.204	-0.246	0.776	2.620
Germany (DE)	0.092	0.044*	0.964	2.728
Sweden (SE)	0.334	-0.090	0.875	2.745

*excluded from further examination due to the coefficient's sign, opposite to the theory

The results of the regression analysis show that Latvian field crop holdings are slightly less sensitive to wheat price fluctuations than the EU average, because the elasticity coefficient for Latvia is by 12% lower than the EU average (see Table 1). At the same time, Latvian field crop holdings are more sensitive to urea (essentially fertilizer) price fluctuations – the absolute value of the elasticity coefficient is by 54% higher than the EU average. It should be noted that, unlike Latvia, in both Estonia and Lithuania, the elasticity coefficients are higher than the EU average: elasticity depending on the wheat price – by 29% and 73%, respectively, elasticity depending on the urea price – by 95% and 133%, respectively.

The factors used in model (3) were selected after testing several potential regression models (with different independent variables. It should be noted that the urea price is included in the regression model because its addition provides better model parameters and model fit (DW, R^2). However, changes in P_{ur} are very closely related to changes in energy prices, and thus this factor affects both output (production prices) and inputs (energy-dependent costs). Therefore, c_3 cannot be used in the economic interpretation of the regression analysis results. It should also be noted that the positive c_2 values for Portugal, Slovakia, Finland and Spain are not economically interpretable. The results of the regression analysis for dairy holdings are presented in Table 2.

Table 2

Regression analysis results for dairy holdings

Country	c_1	c_2	c_3*	R^2	DW
Latvia (LV)	0.465	-0.525	0.302	0.538	2.084
EU 27 Member States (EU27)	0.451	-0.295	0.158	0.859	2.305
Austria (AT)	0.375	-0.084	0.030	0.901	1.588
Belgium (BE)	0.791	-0.520	0.266	0.818	2.363
Bulgaria (BG)	0.308	-0.069	-0.052	0.238	1.552
Czech Republic (CZ)	0.348	-0.037	-0.028	0.699	1.036
Denmark (DK)	0.550	-0.231	0.178	0.827	1.981
France (FR)	0.347	-0.196	0.114	0.852	1.411
Croatia (HR)	0.012	-0.207	0.161	0.183	2.048
Estonia (EE)	0.546	-0.297	0.147	0.828	2.300
Italy (IT)	0.181	-0.141	-0.031	0.511	1.462
Ireland (IE)	0.186	-0.582	0.429	0.409	2.060
Lithuania (LT)	0.452	-0.381	0.320	0.738	1.704
Luxembourg (LU)	0.544	-0.269	0.137	0.762	2.656
Netherlands (NL)	0.753	-0.491	0.226	0.856	2.170
Poland (PL)	0.595	-0.473	0.259	0.667	1.825
Portugal (PT)	0.243	0.058*	-0.052	0.611	1.469
Romania (RO)	0.969	-1.174	0.325	0.623	1.050
Slovakia (SK)	0.060	0.060*	-0.056	0.058	1.479
Slovenia (SI)	0.394	-0.104	0.101	0.872	2.273
Finland (FI)	0.128	0.141*	-0.055	0.926	1.878
Spain (EU)	0.452	0.238*	-0.191	0.696	1.657
Hungary (HU)	0.207	-0.082	0.061	0.460	1.750
Germany (DE)	0.475	-0.403	0.244	0.749	2.180
Sweden (SE)	0.263	-0.251	0.209	0.681	2.381

*excluded from further examination due to the coefficient's sign, opposite to the theory

The results of the regression analysis show that Latvian dairy farms are more sensitive to both fluctuations in the price of raw milk and to the wheat price, which can be considered as fluctuations in the replacement value of feed costs (see Table 2). For example, in Latvia, the elasticity of *OI* to the price of raw milk (c_1) is by 3% higher than the EU average – 0.465 and 0.451, respectively. The elasticity to the wheat price (c_2) differs even more significantly (by 78%): in Latvia – -0.525, on average in the EU – -0.295. Thus, a potentially more unfavourable change (decrease) in the price of raw milk or, especially, a change (increase) in the wheat price will cause a potentially larger decrease in *OI* in Latvia than in the EU average. It should be noted that in Estonia, the elasticity to the price of raw milk is higher than in Latvia, but the elasticity to the wheat price is significantly lower (only 1% higher than in the EU average). In Lithuania, the elasticity of *OI* to the price of raw milk is practically the same as the EU average, but the elasticity to the wheat price is by 29% higher (which is significantly less than in Latvia) than the EU average.

Model (4) consists of 4 factors – pork (grade S) price, price of chicken meat, price of soybean meal and wheat price. The first two characterize the output of the specialization direction, the next two – feed costs (so-called protein components and starch components). The results of the regression analysis of pig farming and poultry farming are presented in Table 3. It should be noted that due to the specificity of the specialization direction (including heterogeneous nature), regression coefficient values that do not correspond to the economic nature are observed for several countries, e.g., $c_1 < 0$, $c_2 < 0$, $c_3 > 0$ and/or $c_4 > 0$. Such elasticities cannot be interpreted economically. In addition, it should be noted that due to the lack of FADN data for 2014, 2015 and 2020, the analysis was not performed for Lithuania.

Table 3

Regression analysis results for granivores holdings

Country	c_1	c_2	c_3	c_4	R^2	DW
Latvia (LV)	0.599	0.330	-0.462	-0.085	0.813	2.914
EU 27 Member States (EU27)	0.266	0.237	-0.279	-0.004	0.810	2.320
Austria (AT)	0.277	0.041	-0.339	0.132*	0.754	1.815
Belgium (BE)	0.123	1.437	-0.626	-0.248	0.885	2.991
Bulgaria (BG)	0.159	-0.222*	0.563*	-0.264	0.354	2.670
Czech Republic (CZ)	0.378	-0.545*	0.719*	-0.356	0.541	2.332
Denmark (DK)	0.785	-0.520*	-0.774	0.408*	0.835	1.540
France (FR)	0.101	0.405	-0.436	0.063*	0.847	2.371
Croatia (HR)	0.153	0.139	1.570*	-0.919	0.932	1.742
Estonia (EE)	0.403	0.556	-0.729	0.006*	0.773	2.690
Italy (IT)	-0.115*	-0.017*	0.524*	-0.327	0.571	2.153
Netherlands (NL)	0.290	1.195	-0.714	-0.166	0.839	3.149
Poland (PL)	0.074	0.364	-0.344	0.091*	0.635	2.818
Portugal (PT)	-0.222*	1.003	-0.548	-0.148	0.736	2.448
Romania (RO)	0.110	-0.440*	0.407*	-0.136	0.260	2.847
Slovenia (SI)	0.115	-0.370*	0.170*	0.101*	0.505	2.846
Finland (FI)	0.169	-0.339*	-0.351	0.268*	0.730	2.403
Spain (EU)	0.305	-0.067*	-0.037	-0.106	0.552	2.583
Hungary (HU)	0.056	0.430	-0.236	0.004*	0.600	2.766
Germany (DE)	0.308	0.487	-0.170	-0.157	0.701	3.040
Sweden (SE)	-0.088*	0.070	-0.154	0.203*	0.350	1.582

*excluded from further examination due to the coefficient's sign, opposite to the theory

The results of the regression analysis show that in Latvia, granivores holdings are significantly more sensitive to changes in external factors than the EU average: the elasticity of *OI* depending on the price of pork is by 125% higher, the elasticity depending on the price of chicken meat – 39% higher, the elasticity depending on the price of soybean meal – 65% higher, the elasticity depending on the price of wheat – 22.0 times higher. It should be noted that in Estonia, *OI* is less sensitive to changes in the pork price (elasticity 51% higher than the EU average), but more sensitive to changes in chicken meat (135% higher) and changes in soybean meal (161% higher).

In summary, from the results of the regression analysis for the three main specialization directions, it can be concluded that in Latvia farms are generally more sensitive to changes in external factors than the EU average. A partial exception is field crop holdings, where the dependence on the price of wheat is lower than the EU average, but at the same time the dependence on the price of urea (characterizing the dependence on fertilizer costs) is higher than the EU average. Thus, it can be concluded that adverse changes in product prices or prices of production factors can have a more negative impact on the competitiveness and profitability of Latvian farms than on average in other EU Member States. However, it should be noted that the results of the regression analysis can be interpreted to a limited extent, because the regression models used explain the *OI* of different countries differently, e.g., in the case of some countries, low R^2, too low or high DW values or/and high p-values for regression coefficients are observed. In addition, for some countries (in the case of certain factors, also Estonia and Lithuania) elasticities are higher than for Latvia. The results are valuable for the elaboration of tailored policy initiatives to promote balanced, monitored development across diverse agricultural specialisations. Future studies should focus on identifying the causes of disparities and on developing effective tools to minimise them among EU agricultural holdings operating in the same common market. Additionally, the socio-economic drivers behind this urea price sensitivity should be studied to determine whether specific technological adoptions might decouple the profitability of Latvian field crop holdings from global chemical market shifts.

Conclusions

1. In Latvian agricultural farms, the Input-Output ratio without subsidies is below 1, which means that market income does not cover costs, so the economic efficiency of the agricultural sector is achieved only with the help of subsidies.
2. Comparing the three main specializations, subsidies play a particularly important role in ensuring profitability in dairy farming in Latvia. Without subsidies the Output-Input ratio in Latvian dairy farms is by 17.4% lower than the EU average, but with subsidies – only by 4.4% lower.
3. Field crop holdings show sensitivity to wheat price and urea price. Latvian field crop holdings are more sensitive to urea (essentially fertilizer) price fluctuations, 54% higher than the EU average. Neighbouring countries, Estonia and Lithuania, also have the elasticity coefficients above the EU average.
4. Dairy farms are more sensitive to fluctuations in the price of raw milk and the wheat price, representing the feed costs sensitivity.
5. Granivores holdings are more complex to be assessed due to dual specialisation included, the findings indicate that the granivores holdings are more sensitive to pork price, poultry price and price of soybean meal. In all these indicators, Latvian farms are more sensitive than the average EU farm.
6. The sensitivity of Latvian farms to volatility is therefore particularly high, taking into account both the low *OI* ratio and the high sensitivity to price fluctuations.

Acknowledgements

The paper was prepared in the framework of the research project “Challenges and Opportunities for Latvia’s Agricultural Sector in the Context of European Union Enlargement” (No. 25-00-S0INZ03-000022).

Authors contributions:

Conceptualization, A.A., A.L., A.A.-E.; methodology, A.A. and A.A.-E.; software, A.A.-E.; validation, A.A. and A.V; formal analysis, A.A and A.V..; investigation, A.A., A.V., A.A.-E. and A.L.; data curation, A.A., A.A.-E.; writing – original draft preparation, A.A.-E.; writing – review and editing, A.A., A.A.-E. and A.V.; visualization, A.A.; project administration, A.A., A.L.; funding acquisition, A.A., A.L. All authors have read and agreed to the published version of the manuscript.

References

[1] Sobolewska A., Bukowski M. Consumption of Nitrogen Fertilizers in the EU - External Costs of Their Production by Country of Application. Agriculture (Switzerland), vol. 15(3), 2025, article 224.

[2] Eidukaitis S., Balezentis T. Agricultural revenue in Latvia, Lithuania, and Poland: An application of the LMDI decomposition. Journal of International Studies, vol. 15 (3), 2022, pp. 9-22.
[3] Bórawski P., Guth M., Parzonko A., Rokicki T., Perkowska A., Dunn, J. W. Price volatility of milk and dairy products in Poland after accession to the EU. Agricultural Economics (Czech Republic), vol. 67(3), 2021, pp. 111-119.
[4] Bórawski P., Pawlewicz A., Parzonko A., Harper J. K., Holden L. Factors shaping cow's milk production in the EU. Sustainability, vol. 12(1), 2020, article 420.
[5] Triatmojo A., Calvia M., Zanon T., Fischer C. Exploring the impact of input costs on farmgate milk prices in EU countries: An empirical analysis. BIO Web of Conferences, vol. 192, 2025, article 05004.
[6] Zawalińska K., Wąs A., Kobus P., Bańkowska K. A framework linking farming resilience with productivity: Empirical validation from Poland in times of crises. Sustainability Science, vol. 17(1), 2022, pp. 81-103.
[7] Vărzaru, A.A. The relationship between economic performance, sustainability, and agricultural productivity: Empirical evidence from the European Union. Agriculture, 16(2), 2026, article 217.
[8] Herman, E. Changes and challenges in EU agricultural holdings and their impact on rural development. Land, vol. 14(5), 2025, article 1080.
[9] Auzina-Emsina A., Auzins A. Modelling of demand shock impact in food sector on sectoral development: Case of Latvia. Engineering for Rural Development, vol. 23, 2024, pp. 338-343.
[10] Lismanis A. Latvijas lauksaimniecības nozares izaicinājumi un iespējas Eiropas Savienības paplašināšanās kontekstā (Challenges and Opportunities for Latvia's Agricultural Sector in the Context of European Union Enlargement). [online] [15.03.2026.] Available at: https://www.arei.lv/lv/projekti/2025/latvijas-lauksaimniecibas-nozares-izaicinajumi-un-iespejas-eiropas-savienibas
[11] European Commission. Farm Accountancy Data Network database. [online] [30.11.2025.] Available at: https://agridata.ec.europa.eu/extensions/FarmEconomyFocus/FADNDatabase.html
[12] Siogkas T., Melfou K., Koutouzidou G., Loizou E., Ragkos A. Structural analysis of farming systems in Western Macedonia: A cluster-based approach. Agriculture, 15(15), 2025, article 1650.
[13] Staniszewski J., Guth M., Smędzik-Ambroży K. Structural conditions of the sustainable intensification of agriculture in the regions of the European Union. Journal of Cleaner Production, vol. 389, 2023, article 136109.
[14] Kryszak Ł., Herzfeld T. One or many European models of agriculture? How heterogeneity influences income creation among farms in the European union. Agricultural Economics (Czech Republic), vol. 67(11), 2021, pp. 445-456.
[15] Poczta W., Średzińska J., Chenczke M. Economic situation of dairy farms in identified clusters of European Union countries. Agriculture, vol. 10(4), 2020, article 92.
[16] AREI. Latvijas lauku saimniecību uzskaites datu tīkls (Latvian Farm Accountancy Data Network). [online] [30.11.2025.] Available at: https://sudat.arei.lv/Login.aspx?ReturnUrl=%2f
[17] IndexMundi. Commodity Prices. [online] [30.11.2025] Available at: https://www.indexmundi.com/Commodities/
[18] European Commission. Agri-food data portal. [online] [30.11.2025] Available at: https://agridata.ec.europa.eu/extensions/DataPortal/home.html
[19] [European Commission. Definitions of Variables used in FADN-FSDN standard results. [16.03.2026.] Available at: https://fadn.pl/wp-content/uploads/2025/02/RICC-1750-Standard-Results-v-February-2025.pdf
[20] Veveris A., Sapolaite V., Dambina L. Productivity of Latvian and Lithuanian rural farms and main factors influencing it. Research for Rural Development, vol. 2, 2016, pp. 113-119. [online] [18.03.2026.]. Available: https://www2.llu.lv/research_conf/Proceedings/22nd_volume2.pdf
[21] Auzins A., Krievina A., Leimane I. Modelling of locally grown plant protein costs for pig feeding. Engineering for Rural Development, vol. 20, 2021, pp. 1304-1311.