IDENTIFICATION OF EXTERNAL SHOCK IMPACT ON AGRI-FOOD SECTOR BY APPLYING OUTLIER DETECTION TESTS: CASE OF LATVIA

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Abstract. Outlier detection tests (e.g. Dixon's Q-test, Grubbs's test) are typically used to check the reliability of data measurement and the reliability of data sets. However, outliers can be caused by other factors, notably external shocks. Recent Russian invasion of Ukraine has caused an enormous geopolitical shock that has affected many countries and sectors including the agri-food sector. The intrinsic feature of the agri-food sector is frequent fluctuations in revenue and costs due to different factors. Thus, apparently extreme variations do not necessarily indicate the impact of an external shock. Moreover, the agri-food sector in Latvia has experienced several shocks previously. Therefore, the long-term historical data on the agri-food sector are highly likely affected by previous shocks, which limits the use of many methods of statistical analysis. The aim of this study is to investigate whether the variations in revenue, cost and income in the agri-food sector were probably caused by this geopolitical shock. The study demonstrates the application of outlier detection tests in order to identify whether the indicators of this sector in 2022 were affected by this geopolitical shock. Although many subsectors exhibited considerable variations in revenue, cost and income, only part of these variations were identified as outliers and thus affected by this geopolitical shock. The rest of them was rather the inherent variations of subsectors. This application of outlier detection tests proposed by the authors is not limited to the agri-food sector or the geopolitical shocks related to Russian invasion of Ukraine. They have wider scope of application. However, further research is required to develop their wider use, especially incorporation into government aid policies.

Keywords: impact of external shock, outlier detection tests, agri-food sector.

Introduction

Russian invasion of Ukraine in 2022 started the largest war in Europe since World War II [1]. This invasion caused an enormous geopolitical shock that affected many countries and sectors and still affects them. This geopolitical shock also affected the agri-food sector. However, the intrinsic feature of the agri-food sector is frequent fluctuations in revenue and costs due to different factors. Thus, apparently extreme variations do not necessarily indicate the impact of an external shock. Meanwhile, these effects can also be attributed to this geopolitical shock [2]. This geopolitical shock has sparked off a debate about how to identify the potential impact of such shock both among academics and practitioners.

A typical approach to identify the impact of an eternal shock would be to use the long-term historical data in order to distinguish between typical (intrinsic) variations and variations caused by external shocks. However, the agri-food sector in Latvia has experienced several shocks previously as well the sector experienced several transformations related to the integration into the European Union and a transition from command economy to market economy some decades ago. Therefore, the use of methods of statistical analysis that require long-term data is hardly possible.

An alternative approach is to use statistical tests that allow operating with small size data samples. Such statistical tests are used to identify and reject extremes, commonly called outliers, in a data set, and their application to analytical data processing is common in all branches of science. Several tests have been applied to detect and remove the outliers from the data. Dixon's coefficient or Q-test is one method of determining outliers in a sample drawn from a normal distribution. The method does not require to estimate the mean and standard deviation. To implement this approach, critical values must be calculated. The use of the method and the calculation of critical values are shown by Verma M.P. *et al.* (2014) [3]. The use of this test can be seen when evaluating the piezometric measurements of the Dobčice dam [4] as well as marine monitoring with waves and weather [5]. Among the tests, Grubbs's test, which was introduced by Grubbs [6] and recommended by the International Organization for Standardization (ISO), has been widely applied for the detection of outliers in the data. There are different applications of Grubbs's test: detecting outlier in flood series [7], water mark detection [8], detecting outliers using smartphones [9], detecting outliers in medicine [10], etc.

The aim of this study is to investigate whether the variations in revenue, cost and income in the agri-food sector were probably caused by this geopolitical shock. Dixon's Q-test and Grubbs's test have been applied in order to achieve this aim. The authors propose a new way how to use outlier detection tests in the evaluation of economic processes (and in engineering economics generally) and to expand their application.

Materials and methods

The main data sources for the study are information and empirical data obtained within the research projects "Assessment of the impact of the Russian military invasion of Ukraine on the agricultural and food sectors and the development of methodology for assessing the impact of market crises on production costs and revenues of the agri-food sectors" (No. 23-00-S0INZ03-000010, 2023) [11]. The study explores both main agri-food sectors – agriculture (crop production, animal production) and food manufacture. The time period 2017-2022 (the same as in the research project) has been examined in this study.

The data set of annual agricultural gross margins calculated by the Latvian Rural Advisory and Training Centre [12] has been used as a data source for both crop production and animal production. These annual agricultural gross margins provide revenue, variable cost, gross margin per crop or livestock category. Due to the stable methodology, these annual agricultural gross margin calculations provide comparable data. The data on revenue, total variable cost and gross margin (including support) in crop production are presented in Table 1.

Table 1

Data on revenue, variable cost and gross margin in crop production (EUR per ha)

Crop	2017	2018	2019	2020	2021	2022
Winter wheat (own equipment, intensive cultivation):						
Revenue	988.00↓	1 147.00	1 004.40	1 132.30	1 050.00	1 568↑
Total variable cost	699.49	596.07	579.47	638.73	510.07↓	1 175.36↑
Agricultural gross margin (including support)	409.95↓	672.11	558.06	636	689.78↑	545.76
Winter oilseed rape (own equipment, intensive cultivation):						
Revenue	1 232.00	1 193.40↓	1 268.20	1 352.80	1 500.00↑	1 498.50
Total variable cost	702.08	636.06	543.12↓	633.02	544.82	967.35↑
Agricultural gross margin (including support)	651.16↓	678.52	858.21	862.21	1 105.03↑	684.27
Spring barley (own equipment, intensive cultivation):						
Revenue	545.24	670.21	507.68	575.40	468.00↓	1 134.00↑
Total variable cost	455.39	410.59	404.90	423.53	335.66↓	721.55↑
Agricultural gross margin (including support)	253.85↓	411.17	281.47	342.78	282.19	607.49↑
Oats (own equipment, intensive cultivation):						
Revenue	618.59	506.49	471.00	604.20	385.00↓	1 225.50↑
Total variable cost	366.61	328.75	317.49	367.81	301.06↓	654.28↑
Agricultural gross margin (including support)	373.22	298.92	286.64	378.82	233.79↓	724.34↑
Faba beans (own equipment, intensive cultivation):						
Revenue	960.00	945.00	945.00	1 100.00	765.00↓	1 560.00↑
Total variable cost	608.13	529.07	455.04	496.20	431.15↓	899.66↑
Agricultural gross margin (including support)	527.13↓	600.31	698.92	823.82	555.79	887.70↑
Potatoes (intensive cultivation for food):						
Revenue	5 778.00	5 760.00	6 080.00	4 900.00↓	6 030.00	8 040.00↑
Total variable cost	2 960.75↓	2 993.85	3 222.48	3 297.60	3 247.95	4 546.95↑
Agricultural gross margin (including support)	2 927.52	2 887.33	2 990.65	1 744.83↓	2 931.90	3 646.17↑

↓, ↑ – the lowest and highest value in the time period 2017-2022 respectively

Source: derived from the Latvian Rural Advisory and Training Centre [12]

According to the study by Auzins *et al.* (2023) [13], the most cultivated cereal and oilseed crops in Latvia are wheat (particularly winter one), oilseed rape (particularly winter one), spring barley, and oats.

Therefore, these crops have been examined. Faba beans and potatoes have been included in the study as they are widespread among pulses and other field crops. The support included in gross margin is comprised of typical subsidies in crop production (animal production as well) – direct payments [12]. Temporary public support, e.g. COVID-19 subsidies, is not included in the calculated gross margins.

The data on revenue, total variable cost and gross margin (including support) in animal production are presented in Table 2. The examined livestock categories (except extensive-reared laying hens) refer to the main subsectors of animal production in Latvia.

Table 2

Data on revenue, variable cost and gross margin in animal production (EUR per animal)

Livestock category	2017	2018	2019	2020	2021	2022
Fattening pigs (intensive rearing):						
Revenue	70.51	65.09↓	145.1	120.93	136.34	150.02↑
Total variable cost	128.34	148.63	149.69	127.65↓	163.66	186.59↑
Agricultural gross margin (including support)	-57.84	-83.54↓	-4.59↑	-6.72	-27.32	-36.57
Dairy cows (intensive rearing):						
Revenue	2 796.73↓	3 134.53	3 201.67	3 494.59	3 871.87	5 608.13↑
Total variable cost	2 264.77↓	2 376.57	2 306.86	2 554.56	2 710.38	3 174.61↑
Agricultural gross margin (including support)	769.21↓	940.55	1 105.05	1 168.60	1 397.36	2 677.62↑
Young cattle for fattening (7-16 months old, intensive rearing):						
Revenue	555.80	582.80↑	322.74↓	393.73	360.07	347.63
Total variable cost	344.96↓	425.26	475.06	442.42	459.27	592.65↑
Agricultural gross margin (including support)	286.57↑	259.56	-43.52	60.32	9.81	-141.02↓
Laying hens (extensive rearing):						
Revenue	27.64↓	35.14	39.84	54.75	59.56	66.64↑
Total variable cost	44.87	52.08↑	30.51↓	37.76	38.85	45.30
Agricultural gross margin (including support)	-17.23↓	-16.94	9.33	16.99	20.71	21.34↑

↓, ↑ – the lowest and highest value in the time period 2017-2022 respectively

Source: derived from the Latvian Rural Advisory and Training Centre [12]

The study deals with almost all subsectors of food manufacture in Latvia, except processing and preserving of fish, crustaceans and molluscs (NACE code rev.2 10.2) and manufacture of vegetable and animal oils and fats (10.4). The former is not related to agri-food sectors, but the latter has an insignificant share in Latvia's food manufacture. The following indicators have been examined – turnover (net sales), cost of goods sold (COGS) and earnings before interest and taxes (EBIT). The data by Lursoft (analytical services), which was obtained within the research project, has been used in this study. In 2022, food manufacture received EUR 9.95 million in one-time government support to mitigate the negative economic impact [11], which affected EBIT in 2022. Thus, EBIT have been adjusted by subtracting this support from EBIT. The data on turnover, COGS and EBIT are presented in Table 3

Table 3

Data on turnover, COGS and EBIT in food manufacture (million EUR)

Subsector	2017	2018	2019	2020	2021	2022
Processing and preserving of meat and production of meat products (10.1):						
Turnover	255.45↓	264.16	266.14	292.02	293.32	356.14↑
COGS	212.66↓	217.97	217.85	234.34	239.61	293.31↑
EBIT	0.76↓	6.43	3.34	9.99↑	5.45	7.58
Processing and preserving of fruit and vegetables (10.3):						
Turnover	85.53↓	89.49	95.21	92.91	88.05	215.40↑
COGS	57.74↓	62.93	64.23	65.35	65.76	158.81↑
EBIT	4.28	5.83	5.90	4.64	3.67↓	12.78↑
Manufacture of dairy products (10.5):						
Turnover	431.14	419.09↓	429.79	430.11	446.80	555.68↑

↓, ↑ – the lowest and highest value in the time period 2017-2022 respectively

Table 3 (continued)

Subsector	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
COGS	382.38	360.94↓	373.70	367.36	390.46	503.50↑
EBIT	7.19	14.93	10.53	15.06↑	10.27	2.65↓
Manufacture of grain mill products, starches and starch products (10.6):						
Turnover	150.34↓	153.38	167.09	208.66	209.68	258.93↑
COGS	126.47↓	130.44	140.35	178.35	179.96	221.22↑
EBIT	3.71↓	4.01	4.28	6.56	4.15	6.95↑
Manufacture of bakery and farinaceous products (10.7):						
Turnover	181.23	177.80↓	193.25	185.78	187.94	203.46↑
COGS	128.55	123.95↓	133.13	128.82	133.77	144.94↑
EBIT	2.41	2.82	8.74↑	5.25	1.92↓	3.54
Manufacture of other food products (10.8):						
Turnover	115.47	89.37	87.84↓	192.12	215.09↑	117.94
COGS	96.12	65.82↓	67.68	140.05	162.48↑	89.13
EBIT	1.27	3.28	0.20↓	8.38↑	6.29	7.29

Source: the authors' calculations based on Lursoft

To investigate whether 2022 agri-food sector indicators were affected by the geopolitical shock, Dixon's Q-test and Grubbs's test have been applied only to indicators with the lowest or highest values in 2022 compared to the 2017-2022 period (see section "Results and Discussion"). Two confidence levels – 90% and 80% – have been used to detect potential outliers. As the agri-food sector is quite volatile, higher confidence level (e.g. 95%) has not been used. Due to the intrinsic fluctuations in the agri-food sector, it is highly likely that these tests will not detect outliers at a higher confidence level.

Regarding Dixon's Q-test, critical Q-values simulated and proposed by Rorabacher have been used in the study: 0.56 ($N = 6$, confidence level 90%) and 0.482 (N = 6, confidence level 90%) [14]. For Grubbs's test, the standard functions of MS Excel have been used to calculate the critical values G. Grubbs's test can be defined as follows [15]:

1. Test whether the minimum value is an outlier:

$$G = \frac{\bar{y} - y_{\min}}{s}. \quad (1)$$

2. Test whether the maximum value is an outlier:

$$G = \frac{y_{\max} - \bar{y}}{s}, \quad (2)$$

where $y_{\min}$ – minimum value of the sample;
$y_{\max}$ – maximum value of the sample;
$\bar{y}$ – sample mean;
s – sample standard deviation.

Results and discussion

Based on the methodology, the data and the assumptions described above, Dixon's Q-test and Grubbs's test have been applied to the indicators of revenue (revenue, turnover), cost (total variable cost, COGS) and income (agricultural gross margin including support), EBIT). Overall, there have been 48 data points. The outlier detection tests have not been applied to the indicators in which the value of 2022 is neither the highest nor the lowest value. In these cases, the result is denoted as "N.A." (see below). Thus, 37 potential outliers (in crop production – 15, animal production – 9, food manufacture – 13) have been tested. In addition, it should be noted that the tests have been also applied to potential outliers that exhibit potentially atypical values for the impact of the geopolitical shock (e.g. the highest value of revenue in 2022, the highest value of income in 2022).

The results of outlier detection in crop production are presented in Table .

Table 4

Results of outlier detection tests in crop production (2022)

Crop	Confidence level 90%		Confidence level 80%	
	Dixon's Q-test	Grubbs's test	Dixon's Q-test	Grubbs's test
Winter wheat (own equipment, intensive cultivation):				
Revenue	Outlier	Outlier	Outlier	Outlier
Total variable cost	Outlier	Outlier	Outlier	Outlier
Agricultural gross margin (including support)	N.A.	N.A.	N.A.	N.A.
Winter oilseed rape (own equipment, intensive cultivation):				
Revenue	N.A.	N.A.	N.A.	N.A.
Total variable cost	Outlier	Outlier	Outlier	Outlier
Agricultural gross margin (including support)	N.A.	N.A.	N.A.	N.A.
Spring barley (own equipment, intensive cultivation):				
Revenue	Outlier	Outlier	Outlier	Outlier
Total variable cost	Outlier	Outlier	Outlier	Outlier
Agricultural gross margin (including support)	Not Outlier	Outlier	Outlier	Outlier
Oats (own equipment, intensive cultivation):				
Revenue	Outlier	Outlier	Outlier	Outlier
Total variable cost	Outlier	Outlier	Outlier	Outlier
Agricultural gross margin (including support)	Outlier	Outlier	Outlier	Outlier
Faba beans (own equipment, intensive cultivation):				
Revenue	Outlier	Outlier	Outlier	Outlier
Total variable cost	Outlier	Outlier	Outlier	Outlier
Agricultural gross margin (including support)	Not Outlier	Not Outlier	Not Outlier	Not Outlier
Potatoes (intensive cultivation for food):				
Revenue	Outlier	Outlier	Outlier	Outlier
Total variable cost	Outlier	Outlier	Outlier	Outlier
Agricultural gross margin (including support)	Not Outlier	Not Outlier	Not Outlier	Not Outlier

N.A. – not possible to assess/detect
Source: the authors' calculations

Table indicates that, when the values of 2022 are the highest values in period 2017-2022, these values are mainly outliers according to both tests as well. The exceptions are agricultural gross margins (including support) for faba beans and potatoes. Additionally, it should be noted that the results differ for spring barley: at confidence level 90% its agricultural gross margin in 2022 is regarded as an outlier by Grubbs's test but not by Dixon's Q-test.

The results of outlier detection in animal production are presented in Table .

Table 5

Results of outlier detection tests in animal production (2022)

Livestock category	Confidence level 90%		Confidence level 80%	
	Dixon's Q-test	Grubbs's test	Dixon's Q-test	Grubbs's test
Fattening pigs (intensive rearing):				
Revenue	Not Outlier	Not Outlier	Not Outlier	Not Outlier
Total variable cost	Not Outlier	Not Outlier	Not Outlier	Outlier
Agricultural gross margin (including support)	N.A.	N.A.	N.A.	N.A.
Dairy cows (intensive rearing):				
Revenue	Outlier	Outlier	Outlier	Outlier

Table 5 (continued)

Livestock category	Confidence level 90%		Confidence level 80%	
	Dixon's Q-test	Grubbs's test	Dixon's Q-test	Grubbs's test
Total variable cost	Not Outlier	Outlier	Outlier	Outlier
Agricultural gross margin (including support)	Outlier	Outlier	Outlier	Outlier
Young cattle for fattening (7-16 months old, intensive rearing):				
Revenue	N.A.	N.A.	N.A.	N.A.
Total variable cost	Not Outlier	Not Outlier	Not Outlier	Outlier
Agricultural gross margin (including support)	Not Outlier	Not Outlier	Not Outlier	Not Outlier
Laying hens (extensive rearing):				
Revenue	Not Outlier	Not Outlier	Not Outlier	Not Outlier
Total variable cost	N.A.	N.A.	N.A.	N.A.
Agricultural gross margin (including support)	Not Outlier	Not Outlier	Not Outlier	Not Outlier

N.A. – not possible to assess/detect
Source: the authors' calculations

Table indicates that the increased values of revenue in 2022 are not outliers according to both tests and at both confidence levels (except dairy cows). Although almost all livestock categories (expect laying hens) experienced a record high total variable cost in 2022, outliers have been detected only in some cases. Moreover, there are three cases when the results differ among the tests and outliers have been detected only by Grubbs's test: flattening pigs (confidence level 80%), dairy cows (confidence level 90%) and young cattle for fattening (confidence level 80%). Only the agricultural margin (including support) of dairy cows in 2022 is an outlier according to both tests (also at confidence level 90%). However, this outlier is quite atypical as dairy cows exhibited a record high not low agricultural margin in 2022.

The results of outlier detection in food manufacture are presented in Table .

Table 6

Results of outlier detection tests in food manufacture (2022)

Subsector	Confidence level 90%		Confidence level 80%	
	Dixon's Q-test	Grubbs's test	Dixon's Q-test	Grubbs's test
Processing and preserving of meat and production of meat products (10.1):				
Turnover	Outlier	Outlier	Outlier	Outlier
COGS	Outlier	Outlier	Outlier	Outlier
EBIT	N.A.	N.A.	N.A.	N.A.
Processing and preserving of fruit and vegetables (10.3):				
Turnover	Outlier	Outlier	Outlier	Outlier
COGS	Outlier	Outlier	Outlier	Outlier
EBIT	Outlier	Outlier	Outlier	Outlier
Manufacture of dairy products (10.5):				
Turnover	Outlier	Outlier	Outlier	Outlier
COGS	Outlier	Outlier	Outlier	Outlier
EBIT	Not Outlier	Not Outlier	Not Outlier	Not Outlier
Manufacture of grain mill products, starches and starch products (10.6):				
Turnover	Not Outlier	Not Outlier	Not Outlier	Outlier
COGS	Not Outlier	Not Outlier	Not Outlier	Not Outlier
EBIT	Not Outlier	Not Outlier	Not Outlier	Not Outlier
Manufacture of bakery and farinaceous products (10.7):				
Turnover	Not Outlier	Not Outlier	Not Outlier	Outlier
COGS	Not Outlier	Outlier	Outlier	Outlier
EBIT	N.A.	N.A.	N.A.	N.A.

Table 6 (continued)

Subsector	Confidence level 90%		Confidence level 80%	
	Dixon's Q-test	**Grubbs's test**	**Dixon's Q-test**	**Grubbs's test**
Manufacture of other food products (10.8):				
Turnover	N.A.	N.A.	N.A.	N.A.
COGS	N.A.	N.A.	N.A.	N.A.
EBIT	N.A.	N.A.	N.A.	N.A.

N.A. – not possible to assess/detect
Source: the authors' calculations

Almost all the subsectors of food manufacture experienced record high turnover and COGS in 2022. At confidence level 90%, the outliers have been detected in three subsectors – processing and preserving of meat and production of meat products, processing and preserving of fruit and vegetables, and manufacture of dairy products (see Table). If confidence level 80% is considered, outliers are observed also in manufacture of grain mill products, starches and starch products (does not refer to COGS), and manufacture of bakery and farinaceous products. Nevertheless, there are mixed results for these two subgroups: the outliers of turnover have been detected only by Grubbs's test.

Only manufacture of dairy products experienced very low EBIT in 2022. However, this value is not an outlier according to both tests. Processing and preserving of fruit and vegetables, and manufacture of grain mill products, starches and starch products experienced record high EBIT in 2022, which is not a typical impact of geopolitical shock. However, the outliers have been detected only in processing and preserving of fruit and vegetables.

Generally, the results of the study, i.e. identified 24-28 outliers at confidence level 80% and 21-24 outliers at confidence level 90% (see below), suggest that Russian invasion of Ukraine probably affected the indicators of the agri-food sector in Latvia. Nevertheless, this impact was not always typical, e.g. many revenue indicators and even income indicators reached the highest values in 2022. Moreover, the cost outliers were quite frequently offset by revenue outliers or high revenue.

In most cases, Dixon's Q-test and Grubbs's test have yielded the same result: 24 and 21 outliers have been detected by both tests at confidence levels 80% and 90% respectively. However, the divergent results have been observed in 4 cases at confidence level 80% and 3 cases at confidence level 90% when the outlier has been detected only by Grubbs's test. These results imply that there is a higher probability to detect the outlier by Grubbs's test. Overall, these findings likely comply with the recommendation of ISO to use Grubbs's test. Further research is required to determine whether one of these tests is more appropriate for the identification of the impact of external shocks. Such further research is essential to broaden the application of outlier detection tests and incorporate their use into government aid policies.

Conclusions

1. The application of outlier detection tests demonstrates that not all potential outliers (37 tested) are outliers according to Dixon's Q-test and Grubbs's test. 24 and 21 outliers have been detected by both tests at confidence levels 80% and 90% respectively. The divergent results have been obtained, too.
2. The results of the study imply that there is a higher probability to detect the outlier by Grubbs's test than Dixon's Q-test.
3. The identified outliers suggest that Russian invasion of Ukraine probably affected the revenue, cost and income indicators of the agri-food sector in Latvia. However, this impact was not always typical. Moreover, the cost outliers were quite frequently offset by revenue increase (even revenue outliers).
4. Further research is required to broaden the application of outlier detection tests for the identification of the impact of external shocks and the incorporation of their use into government aid policies.

Acknowledgements

The paper was prepared in the framework of the research project "Assessment of the impact of the Russian military invasion of Ukraine on the agricultural and food sectors and development of methodology for assessing the impact of market crises on production costs and revenues of the agri-food sectors" (No. 23-00-S0INZ03-000010).

Author contributions

Conceptualization, A.Auzins; methodology, A.Auzins and A.Aboltins; validation, A.Auzins and A.Aboltins; investigation, A.Auzins and A.L.; data curation, A.Auzins and A.L.; writing-original draft preparation, A.Auzins, A.Aboltins and A.L.; writing-review and editing, A.Auzins, A.Aboltins and A.L.; visualization, A.Auzins; project administration, A.Auzins. All authors have read and agreed to the published version of the manuscript.

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