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Consequences of russia's military invasion of Ukraine for Polish-Ukrainian trade relations

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Abstract. An accurate forecast of interstate trade volume allows for short-term and long-term planning, particularly deciding on state budget revenues, foreign exchange earnings, border arrangement, other infrastructure, migration and social policies. Hostilities are destructive so the russian military aggression against Ukraine in 2022 needs to be assessed in terms of its effects on key economic aspects of Polish-Ukrainian relations, as Poland has been the main economic, trade and social partner of Ukraine in recent years. This article analyses the trade dynamics between the two countries since 2005. It was found that since 2015 the main trends of this dynamics have changed. Monthly data from 2015 to 2021

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were used for modelling and forecasting. Relevant SARIMA and Holt-Winters exponential smoothing models were built. These models forecast the volume of trade for the fourth quarter of 2021 and the first quarter of 2022. The relative errors of forecasting (compared to actual data) for October, November and December 2021 were as follows: according to the SARIMA model – 0.8%, 3.6% and 2.3%, respectively; for the Holt-Winters model – 1.9%, 3.6% and 0.7%, respectively. Given the expectations and consequences of russia's military aggression against Ukraine, the average projected trade turnover between Ukraine and Poland was reduced by 20% per month for the first quarter of 2022. In comparison with the available actual (preliminary) data for January 2022, such a pessimistic forecast gave the following relative forecasting errors: according to the SARIMA model – 3.8%; according to the Holt-Winters model – approx. 1%.

Keywords: trade, Poland, Ukraine, russian military aggression, time series, forecasting.

JEL Classification: H56, F17, P33

1. INTRODUCTION

The trade between Poland and Ukraine is a good reflection of the economic relations between these countries, which have recently experienced several turning points: 1) the signing of an association agreement between the European Union and Ukraine; 2) russia's military aggression against Ukraine in 2014 and 2022; 3) weakening of Poland's migration policy aimed at attracting labour to the Polish market; 4) allowing of visa-free travels for Ukrainian citizens to the EU. Another wave of russian military aggression against Ukraine began on 24 February 2022. A number of countries provide economic, military, financial and other assistance to Ukraine, which evidences the understanding that in a globalised world, military conflict, redrawing and political change in one country can significantly affect economic and other indicators around the world (Krpec & Hodulak, 2019). Migration crises, transport corridors, supply chain disruption and loss of trade relations are some of the problems faced by states that are not direct participants in the war but experience its impact (Docquier et al., 2018). Particularly acute difficulties are felt by countries that have the closest economic relations with the conflict participants and are closest territorially, as per the first law of geography by W. Tobler, "everything is related to everything else, but near things are more related than distant things" (Tobler, 1970). Therefore, during russia's aggression against Ukraine, Polish-Ukrainian economic relations may suffer losses and experience complications that need to be assessed.

This study complements the literature and fills the gaps in it in two ways: first, the dynamics of export-import operations and turnover between Ukraine and Poland are studied based on the latest data; second, the development of Polish-Ukrainian trade relations is predicted through the use of additive models of the Box-Jenkins series of dynamics SARIMA model with a seasonal component and the Holt-Winters exponential smoothing model).

Thus, this study aims to forecast the economic consequences of export-import operations between Poland and Ukraine under the influence of russian military aggression against Ukraine.

The article continues as follows. The following section presents the prerequisites that determined the study's relevance. Section 3 is devoted to reviewing the literature related to this study's topic and the historical body of knowledge about Polish-Ukrainian trade relations. Section 4 describes the data used in the analysis and the methodology applied to modelling and forecasting. Section 5 provides the results of our

research. Section 6 discusses the research results and how they can be interpreted in terms of previous research. Finally, the conclusions are presented in Section 7.

2. BACKGROUND

In 2014, the European Union and Ukraine signed an association agreement, the economic purpose of which is, in particular, "to establish conditions for enhanced economic and trade relations leading towards Ukraine's gradual integration in the EU Internal Market, including by setting up a Deep and Comprehensive Free Trade Area" (Association Agreement; Vatamanyuk-Zelinska & Melnychenko, 2020). One of the most important aspects of this agreement is Title I, "Trade and trade-related matters", according to which "each Party shall reduce or eliminate customs duties on originating goods of the other Party" in accordance with the rates set out in the agreement. This step has unambiguously boosted trade between Ukraine and EU members. As a result, Poland has become one of the key economic partners for Ukraine in the European Union and in general among partner countries. The trade turnover between the countries from 2005 to 2014 amounted to USD 6.4 billion and exceeded USD 7.4 billion in 2020. Thus, in 2020, the most goods among the EU countries (USD 3,272,683.09) were exported to Poland from Ukraine. In the second place was Germany (USD 2,071,739.39) and Italy in third place (USD 1,928,906.26). If we talk about Ukraine's foreign economic relations globally, not only in Europe, Poland ranks second after China, to which Ukraine supplied the most goods (USD 7,099,948.15) in 2020 (Foreign trade in goods by partner countries, 2020).

In addition, among the EU member states, Poland issues the most residence permits to non-EU citizens (598,000 first residence permits in 2020), followed by Germany (313,000), Spain (312,000), France (226,000) and Italy (106,000). In 2020, the Polish authorities issued 81.3% of all residence permits to Ukrainians (Residence permits - statistics on first permits issued during the year). According to the last census in Poland in 2020, the number of foreigners living in Poland is 2,106,101, including 1,351,418 Ukrainians (64.2%) (Foreigners population in Poland during COVID-19). Such statistics, however, do not reflect the actual situation and full-fledged economic activity of Ukrainian citizens who travel and stay in Poland for economic purposes. The lack of accurate data stems from Ukrainians working without registration and employment contracts within the 90 days during which they are allowed to stay in Poland as part of visa-free travel (Regulation (EU) 2017/850). They enter Poland as tourists but work illegally instead, for example, as seasonal workers (Fiałkowska & Matuszczyk, 2021; Górny & Kaczmarczyk 2018).

More migrants arrived in Poland after the full-scale invasion of Ukraine by russian troops in February 2022, which A. Umland (Umland, 2022) explains as an "appetite for Ukrainian territories and displeasure with Ukrainian independence". According to the author, "neo-imperial thinking and unwilling to respect the borders and independence of various neighbours, as well as the rule of international law in the post-Soviet space", led to significant military conflict between Ukraine and russia, the Crimea annexation and war in the Donbas. This was avoided only through close trade ties and energy cooperation between the countries until then. Active hostilities in Ukraine, which began in 2014, on the one hand, as well as Poland's pro-immigration policy, aimed at attracting migrants to work and fill vacancies in the Polish labour market, on the other hand, led to increased migration of Ukrainian citizens to Poland (Brunarska et al., 2016, Maruszewski & Kaczmarczyk, 2020). As of 7 April 2022, 2,548,000 people arrived in Poland from Ukraine after 24 February 2022 (Border guard). Of course, some of them have left for other countries, and some have already returned to Ukraine. However, the largest percentage of them remains in Poland.

Thus, the growth of economic activity between the two countries was influenced by the following key factors: 1) russia's military aggression against Ukraine in 2014 and 2022 and declining living standards in 2014 forced Ukrainians to travel to Poland in search of security and economic prosperity. In 2022 after the full-scale invasion, security, of course, came first after significant threats; 2) relaxing the migration policy of

Poland to attract labour to the Polish market in order to fill vacancies arising from the development of the Polish economy and the outflow of the workforce to other countries (UK, Germany, etc.), as well as the practical elimination of restrictions on crossing Polish-Ukrainian border refugees from Ukraine after 24 February 2022; 3) the opportunity of visa-free travel for Ukrainian citizens to the EU with a biometric passport and staying up to 90 days for tourism, which is often used for illegal work during this period, or to find legal work and legal stay in the country; 4) signing an association agreement between the European Union and Ukraine; 5) territorial proximity between countries, as well as linguistic and cultural similarity of countries. In addition to migration, these factors have also led to a significant strengthening of trade ties between countries. Therefore, after 2014 some migrants from Ukraine started their own businesses and established trade using ties with Ukraine (Borkowski et al., 2021). Thus, commerce between Poland and Ukraine is of interest to study because of its importance in relations between the two countries. It is an important indicator that reflects economic interstate relations.

3. LITERATURE REVIEW

The literature on the research topic can be divided into three areas: (i) emphasis on the importance of interstate trade relations; (ii) study of Ukrainian-Polish relations and their trade component; (iii) study of forecasting methods to identify the most suitable for forecasting export-import operations after the invasion of the russian Federation (RF) of Ukraine in February 2022.

3.1. The importance of trade in the modern world

This study focuses firstly on confirming the importance of international trade in the development of society and its importance in the modern world. In a globalised world, disruption of supply chains in the international trade system can cause significant problems for business development (Scheibe & Blackhurst, 2018). The effects of the COVID-19 pandemic, which has disrupted a significant number of supply systems in the global economy, national and regional trade relations, firms and individual households, are clear evidence of this (Mena et al., 2022; Burki, 2020; Melnychenko, O. (2021; Shkodina et al., 2020; Mas-Coma et al., 2020). In fairness, however, it should be noted that in some industries, such as medical devices, the Covid-19 pandemic has had a positive impact (Hayakawa & Mukunoki 2021), which is logical given the huge increase in demand for various product groups in this area. At the same time, without a properly organised trade system, overcoming the pandemic would be impossible as "quick and global access of medicines and vaccines to patients remains an important goal even outside of a pandemic" (Goldrick et al., 2022). In addition, the scientific literature shows that international trade affects the intensity of emissions of pollutants (Ma & Wang 2021; Duan et al., 2021), energy consumption and its sources (Melnychenko, 2021; Osadcha & Melnychenko, 2021; Osadcha et al., 2021; Rahman, 2021; Zhang & Duan, 2020), transport development (Strandenes, 2021), employment (Mertens, 2020; Egger et al., 2020; Dix-Carneiro & Kovak, 2019; Afonso & Holland, 2018), inflation rate, environment (Hulme, 2021), etc.

Thus, trade as a sphere of economic activity in general, and the supply system in particular, play a key role in society's development and its normal functioning. Therefore, the analysis of trade policy and relations and other aspects of the trade is one of the most critical factors that help assess, in particular, interstate relations and changes in them based on changes in trade performance.

The impact of trade relations on conflicts, including military ones (Polachek, 1980; Barbieri, 1996; Oneal & Russett, 1999), or international trade as a weapon (Lee, 2022) is widely studied in the scientific literature. Most research focuses on the generally accepted liberal view that commerce reduces the likelihood of military conflict (Lee & Pyun, 2016; Chen, 2021) because "trade is economically beneficial, military conflicts reduce trade, and leaders are rational" (Martin et al., 2008). At the same time, attention is often

paid to the conflict sides, which are also trading partners. Moreover, if these countries sell similar goods on the world market, they are more likely to go to war, even if their bilateral trade ties are solid and substantial (Chatagnier & Kavaklı, 2017). This study focuses on the impact of the military conflict between the two countries on their neighbouring country – Poland.

3.2. Polish-Ukrainian trade relations

The study of Polish-Ukrainian trade relations is not a popular topic in scientific publications for various reasons. They include a low trade turnover between the countries in comparison with other states, a low number of publications in international scientific journals by Ukrainian scientists who could be interested in such research to develop proposals for business and the state, and disinterest in the topic of Polish scientists who are traditionally concerned about trade with Western partners and those with much higher turnover. This is evidenced by the fact that, despite russia's ongoing war against Ukraine, the National Bank of Poland expects to maintain an advantageous domestic situation due to the small share of exports to Ukraine and russia in Polish foreign trade (Narodowy Bank Polski, 2022). The search of scientific literature in the SCOPUS database by the keywords "Ukraine" and "Poland" in the titles of articles yielded 338 results (as of 13 April 2022). It was reduced to 60 by limiting the subject area to "Economics, Econometrics and Finance" and "Business", Management and Accounting", with only three publications directly related to the study of trade between Poland and Ukraine. One such study concerns a simple calculation of the comparative advantages of individual product positions in Polish exports in the domestic market of Ukraine (Motoryn et al., 2020). Other scholars conducted a more thorough study to identify features of regional differentiation of trade between Ukraine and Poland to find out the differences between the volume of export-import transactions among the regions of Ukraine, finding that trade between Ukraine and Poland directly depends on the population, the share of their gross regional product and the territorial proximity of the regions to Poland due to the established trade relations with Polish partners (Lazhnik et al., 2020). Thus, Kyiv is the main importer of Polish goods, and the Ternopil and Volyn regions, with relatively smaller volumes of gross regional product and population, occupy a unique position with a high level of trade with the Polish side.

An early study examines the impact of the global financial crisis and key macroeconomic indicators on foreign trade between Ukraine, China and Poland. It offers some recommendations to reduce the effects of financial destabilization on Ukraine's economic development (Shcherbata, 2009).

All these publications are by Ukrainian scientists, which confirms our statement about the reasons for the unpopularity of this topic among the international scientific community. However, against the background of the military confrontation between Ukraine and russia, it is necessary to analyse the Ukrainian-Polish trade relations with a new approach and assess the possible impact of the consequences of russia's military aggression against Ukraine.

3.3. International trade transaction forecasting methods

Several methods are available to forecast the values of economic, social and natural variables, among other things. Popular today are the medium approach, naive approach, drift method, seasonal naive approach, time series methods, econometric forecasting methods, artificial neural networks, etc. (Melnychenko, 2020; Melnychenko et al., 2021). In economics, methods related to time series modelling and econometric forecasting are widely used. One of their significant examples is the Box-Jenkins model (Box & Jenkins, 1976), a multicomponent transfer function with an autoregressive moving average error structure. It has been used in early studies to assess, among other things, the relationship between inflation and unemployment (Whiteley, 1984) and airport passenger traffic forecasting (Tsui et al., 2014). Despite the

relative simplicity of these models, their application (especially autoregressive, which takes into account the impact of previous values on subsequent ones) provides advantages in forecasting over other models: not only over popular artificial neural networks but also with very large and expensive multidimensional macro models of simultaneous equations (Granger, 2007). There is evidence in the literature that "artificial neural networks and non-parametric regressions, in many cases, perform better than structural econometric models and SARIMA models", but this conclusion depends on the choice of input variables (especially their number) when it is necessary "to capture the effects of sudden changes and chaotic patterns of macroeconomic variables in developing economies" (Chuku et al., 2019). In this case, Grillenzoni (Grillenzoni, 1998) argues that "for forecasting time series with trends and cycles whose pattern changes over time" and for time series that are asymptotically unstable and essentially nonstationary, it is advisable to use Boxing-Jenkins models. It is noteworthy that similar conclusions are found in Matskul (Matskul et al., 2020).

4. DATA AND METHODOLOGY

4.1. Data

Data for analysis are available on the website of the State Statistics Service of Ukraine (The State Statistics Service of Ukraine). The data are available on the monthly export, import and trade turnover (as the sum between export and import between Ukraine and Poland) starting from January 2005 and ending in December 2021. This is about 204 input data. The unit is USD million. Preliminary data processing was carried out in MS Excel spreadsheets. When modelling and computing were performed in DELL STATISTICA software, version 12.

Figure 1 shows the dynamics of export, import and trade turnover.

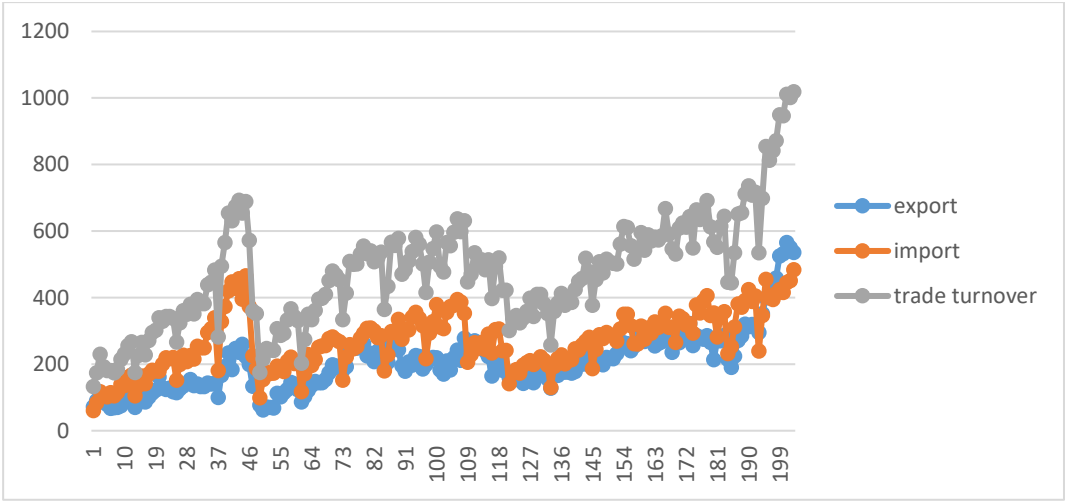


Figure 1. The dynamics of export, import and trade turnover (USD million) between Ukraine and Poland from January 2005 (1) to December 2021 (204)

Source: Authors' calculations

The descriptive characteristics of the data are given in Table 1.

Table 1

Characteristics (USD million) of the data file

Variable	Average	Minimum	Maximum	Standard deviation
Export	205.3669	61.9	505.8	90.82426
Import	267.9818	60.4	483.5	88.17746
Trade Turnover	472.3487	132.8	1019.0	168.9019

Source: Authors' calculations

The main characteristics of the studied dynamic series allow us to conclude that there are no anomalous levels (the so-called "outliers"), i.e. levels that fall outside the mean plus or minus three standard deviations. Considering the entire period under study from 2005 to the present, it becomes necessary to use relatively complex models with piecewise linear trends for modelling. It can be seen in the example of trade turnover between the countries. In the future, modelling and forecasting will be carried out for the dynamics of trade relations between Ukraine and Poland (modelling and forecasting exports and imports is carried out similarly). Using the "Nonlinear Estimation" Statistics program module, one can build a piecewise linear trend for the variable TT (trade turnover).

Table 2

Parameters of the piecewise linear trend for the TT variable over the entire studied interval.

N=204	Model: piecewise linear with break points (Data Table 1) Dependent variable: TT Loss Function: Least Squares Total losses: 1556740.7 R=0.85432 Explained variance.: 72.				
	B0	t	B0	t	P.piecewise
Grade	261.5225	1.07620	445.5149	1.17653	473.3487

Source: Authors' calculations.

Analysis of the dynamics of the entire study period (2005-2021) shows a change in the main trend during 2015. Namely, during 2005-2014 the trend is given by the equation y = 261.52 + 1.08 * t (t = 1,2,..., 120), and during 2015-2021 the trend equation is y = 445.51 + 1 , 18 * t (t = 121, 122, …, 204). Since the task is to make long-term forecasting (not retrospective analysis), the study uses the data from 2015 to 2021, which greatly simplifies the time series models.

4.2. Methodology

This study uses the Box-Jenkins model for forecasting exports, imports and trade turnover between Poland and Ukraine based on actual historical data from 2015 to 2021. The Box-Jenkins models are multicomponent structure models (additive or multiplicative) that track all past values of a variable and its stochastic components to predict values for all future periods (Das, 2020).

This study applies the following Box-Jenkins additive models of time series (without cyclic component, taking into account the studied dynamics):

$$y_t = f(t) + S_t + e_t, \tag{1}$$

where y_t is a level of time series at time $t = 1,2,...$; $f(t)$ – trend is traced long-term and evolution is deterministic in time; S_t – seasonal fluctuations; e_t – random fluctuations. This design allows analysing, modelling and predicting each component separately, eliminating it.

One of the above model variants is the SARIMA model (AR – autoregressive, I – integrated, MA – moving average, C – with seasonal component). Noteworthy, the model can be applied only to stationary

time series, i.e. the random component must satisfy the condition $e_t \in N(0;\sigma)$ or be the so-called "white noise". This is achieved by eliminating the trend (in other words, by transforming a number of dynamics by taking differences of a certain order – a discrete analogue of derivatives). Next, the order of autoregression (autocorrelation) is identified by finding autocorrelation coefficients. The seasonal component is sought using Fourier analysis. Still, this study offers a simpler way, consisting of visual analysis, i.e. constructing segments of the whole series of dynamics over certain periods (in our case – years) and estimating their approximate parallelism. Finally, the process of smoothing using a moving average (it is recommended to use the principle of minimum sliding of the first order). The final SARIMA model is as follows:

$$y_t = p_{t-1}y_{t-1} + f(t) - q_{t-1}e_{t-1} + S_t, \quad (2)$$

where y_t is the level of time series; $f(t)$ is a trend component; p_{t-1} is the auto-regression coefficients of the first order; q_{t-1} is a coefficient of the moving average model; e_{t-1} is an irregular component (random deviations or so-called white noise). This study applies the smoothed moving average of the first order $S_t = c + Q_{t-1}S_{t-1}$ to find seasonal coefficients.

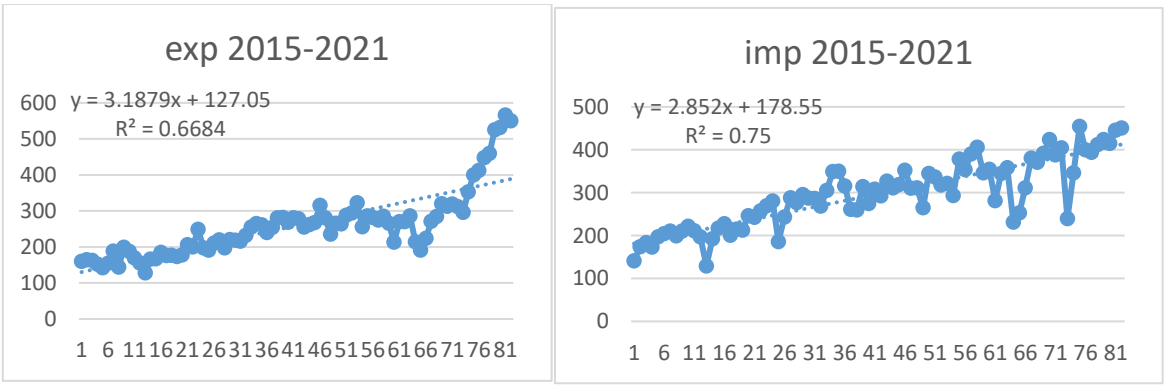
Another variant of the Box-Jenkins model is the Holt-Winters model (Holt, 2004; Winters, 1960). The main difference of this model is that the smoothing of the components of the time series involves exponential smoothing, i.e.:

$$y_{t+1} = \alpha y_t + (1-\alpha)y_{t+1}, \quad t = 1,2,\ldots. \quad (3)$$

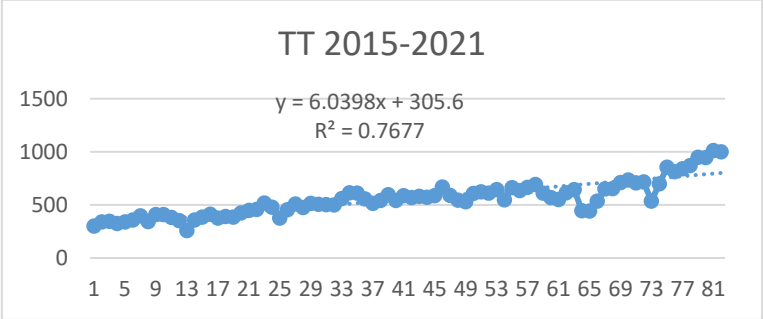
The peculiarity of this smoothing is that the last levels of the time series are more significant. For example, the smoothing parameter value means that 10% of the last levels of a series of dynamics determine 90% of the forecast. However, the application of the Holt-Winters model does not require (unlike SARIMA) stationary time series.

5. EMPIRICAL RESULTS

Figure 2 shows the dynamics of export, import and trade turnover (respectively – export (exp), import (imp) and trade turnover (TT) variables) between the countries.



a) b)



c)

Figure 2. The dynamics of export, import and trade turnover between Ukraine and Poland from January 2015 (1) to December 2021 (84) with trends: a) export; b) import; c) trade turnover

Source: Authors' calculations

Significant is the steady increase in the volume of export-import and trade turnover operations between the countries after signing the Agreement on the Free Trade Zone between Ukraine and the EU (even despite the COVID-19 pandemic) as a stable positive trade balance between Ukraine and Poland. This study uses modelling and forecasting trade turnover (modelling and forecasting are performed similarly for export and import) dynamics based on one of the Box-Jenkins models (1) – the additive model SARIMA. At the same time, for modelling, this study employs the levels of the time series from January 2015 to August 2021, leaving the available data (3 levels) to check the quality of the forecast. It is necessary to carry out the model identification process for correct modelling. It is required to create a trend first (the standard least squares method is used to find the trend component).

$$f(t) = 6.0398t + 305.6 \tag{4}$$

As is known, a necessary condition for the application of the SARIMA models is the requirement that the time series be stationary. Figure 3 shows that the time series is stationary after trend elimination (which is done by taking the first-order difference on lag 1). In other words, random deviations e_t are the so-called "white noise", i.e. $e_t \in N(0,\sigma)$.

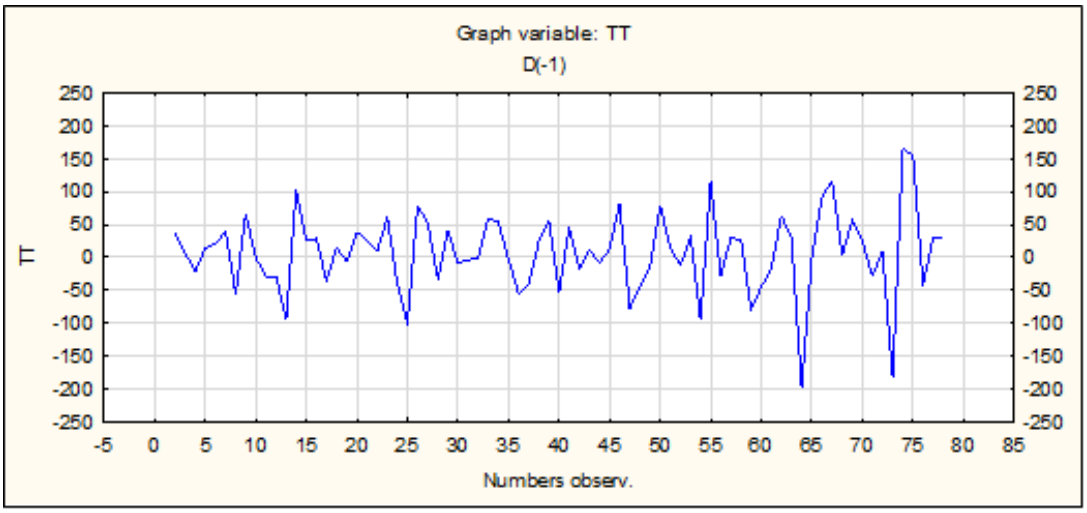
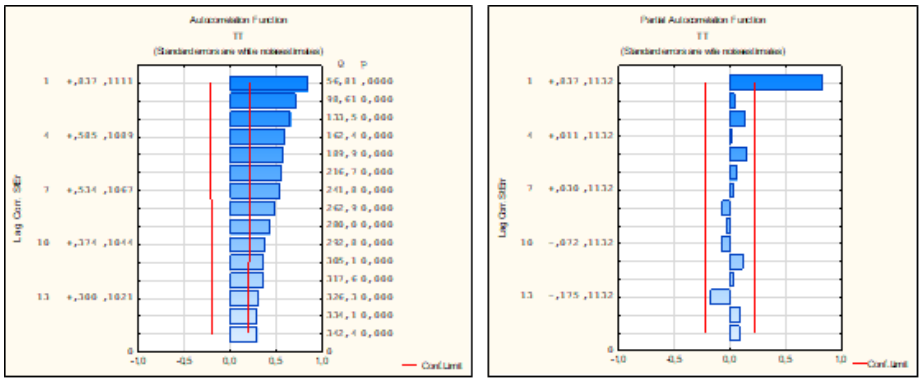


Figure 3. Graph of time series (variable TT) after trend elimination

Source: Authors' calculations

Next, it is necessary to find a sequence of autocorrelation coefficients, i.e. the correlation coefficients of the original series with the same series shifted by one step. Still, given that this autocorrelation entails higher-order autocorrelations, it is necessary to find a sequence of partial autocorrelation coefficients in two steps. The search results of autocorrelation and partial coefficients are shown graphically in Figure 4. Analysis of graphs allows concluding that there is only a first-order correlation.

The analysis of graphs of autocorrelation and partial autocorrelation functions makes it possible to establish the presence of first-order autocorrelation on lag 1 and the absence of higher-order autocorrelations.



a) **b)**

Figure 4. Graphs of autocorrelation (a) and partial autocorrelation (b) functions

Source: Authors' calculations

The next step in establishing the SARIMA model is the identification of seasonality. In general, it is necessary to use Fourier analysis. But this study offers a more straightforward solution. MS Excel can be used to build graphs of our time series by years: 2015, 2016, ..., 2020.

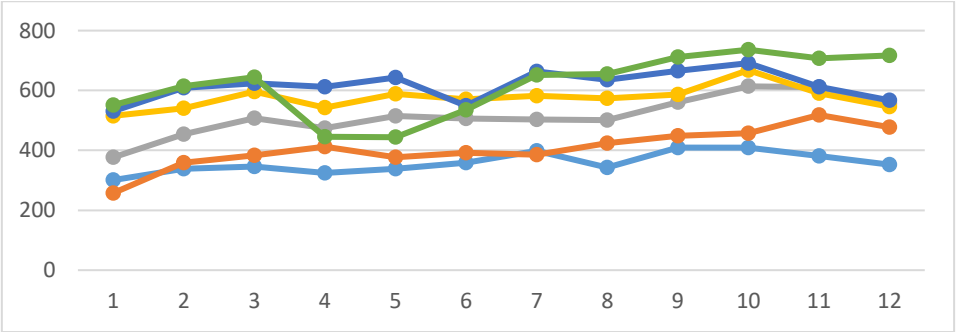


Figure 5. Graph of our time series by years: 2015, 2016, ..., 2020.

Source: Authors' calculations

The approximate parallelism of the dynamics over the years allows stating that there is an annual seasonality at lag 12. Thus, the model identification process is completed. To find parameter estimates of the SARIMA model and forecasts, this study uses the "Time series and forecasting" module of the STATISTICS program. The trend is eliminated by transforming the time series by taking the first-order differences at lag 1. Finally, the SARIMA models for the variable TT have the following form (see (2):

$$y_t = p_{t-1}y_{t-1} + f(t) - q_{t-1}e_{t-1} + S_t \quad , \tag{5}$$

where $y_t, t = \overline{1,81};$ is the level of time series; $f(t) = 6.0398t + 305.6$ (see Formula (4)) is a trend component; p_{t-1} is the auto-regression coefficients of the first order; q_{t-1} is a coefficient of the moving average model; e_{t-1} is an irregular component (random deviations or so-called white noise). The study applies the smoothed moving average of the first order $S_t = c + Q_{t-1}S_{t-1}$ to find seasonal coefficients. Parameters of the model should estimate at a 95% confidence level (or 5% risk) with the condition of minimising the MSE (mean square error):

$$MSE = \sum_{i=1}^{n} \frac{(y_i - \tilde{y}_i)^2}{n} \quad , \tag{6}$$

where y_i is the actual value and $\tilde{y}_i$ estimates indicator y at period i. As a result, we obtained the following parameter estimates (Table 3).

Table 3

Parameter estimates of the model SARIMA

Variable	TT (trade turnover)			
Parameter	Estimate	Asymptotic standard error	Asymptotic t-statistic	p-level
p_{t-1}	0.500984	0.237957	2.10535	0.038654
q_{t-1}	0.728480	0.188825	3.85796	0.000242
Q_{t-1}	-0.393143	0.124564	-3.15616	0.002313

Source: Authors' calculations

The closeness confirms the adequacy of the SARIMA models to the normal law of the distributions of residuals (differences between the actual and modelled levels of the time series), which are presented in Figure 6.

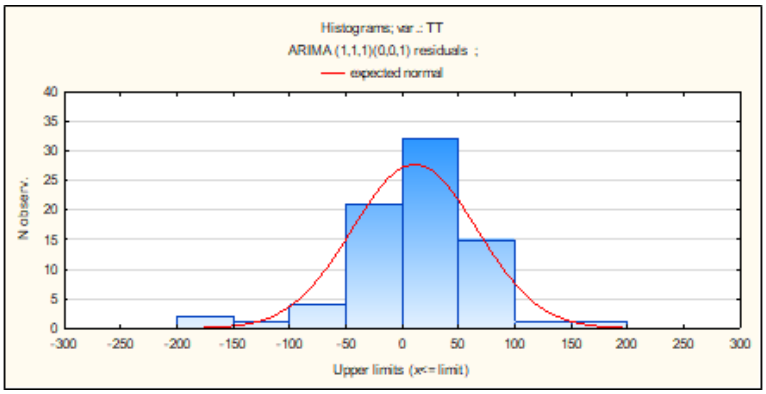


Figure 6. Graph of distribution normality of the residuals of the models

Source: Authors' calculations

The constructed models are applied to predict trade turnover volumes (variable TT) for the fourth quarter of 2021 (t =82, 83, 84) and the first quarter of 2022. The following formulas determine forecasting results and relative forecasting errors:

$$\delta_t = \frac{\left| y_t^{predict} - y_t^{actual} \right|}{\left| y_t^{actual} \right|} \quad ; \quad t = 82, 83, 84 \quad , \tag{7}$$

Table 4

Forecasts for the SARIMA model and actual data

Trade turnover (TT)		
Forecasts	Actual	Residuals
1019.870	1011.4	0.008375
1038.001	1001.3	0.036653
1043.427	1019	0.023971
973.066	749.019	-
992.996	-	-
1010.06	-	-

Source: Authors' calculations

Table 4 shows that the relative prediction errors for the variable TT are: for September 2021 – 0.8%; for November 2021 – 3.6%; for December 2021 – 2.3%. This indicates relatively high adequacy of the constructed SARIMA model for further forecasting.

Therefore, applying the Holt-Winters exponential smoothing model was considered necessary for modelling and forecasting. The simulation again uses the "Time Series and Prediction" module of the STATISTICS program. Before building the Holt model, the so-called "search on the grid" is conducted to find the optimal values of the smoothing parameters. As a result, the following values were found: the smoothing parameter of the main process alpha=0.6; smoothing seasonal component parameter delta=0.1; trend damping parameter phi=0.1. Table 5 shows the results of modelling and forecasting.

Table 5

Results of the modelling and forecasting (fragment) using the Holt-Winters exponential smoothing model

Observation	TT	Smoothing TT	Residual	Seasonal component
1	300.7000	246.706	53.994	-90.1222
2	338.9000	372.958	-34.058	-3.8294
3	346.0000	388.655	-42.655	26.7840
4	324.4000	307.298	17.102	-31.9392
5	338.8000	332.252	6.548	-21.2318
6	359.0000	332.065	26.935	-29.7264
7	398.5000	399.565	-1.065	15.6182
8	343.3000	392.866	-49.566	3.6271
9	409.3000	402.800	6.500	40.3439
10	409.2000	435.267	-26.067	65.5640
11	380.8000	388.813	-8.013	32.9675
12	352.4000	344.284	8.116	-8.0556
…	...	…	…	…
82		1038.266		
83		1026.212		
84		1006.708		
85		946.941		
86		1050.057		
87		1105.937		

Source: Authors' calculations

The adequacy of the obtained Holt-Winters exponential smoothing model is confirmed by analysing the histogram of residuals and the normal curve (Figure 7).

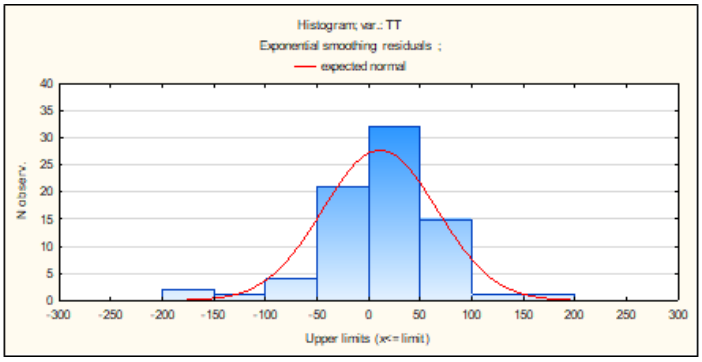


Figure 7. The histogram of the residuals

Source: Authors' calculations

Figure 8, which shows the original and simulated time series and residual, clearly demonstrates the quality of the constructed model.

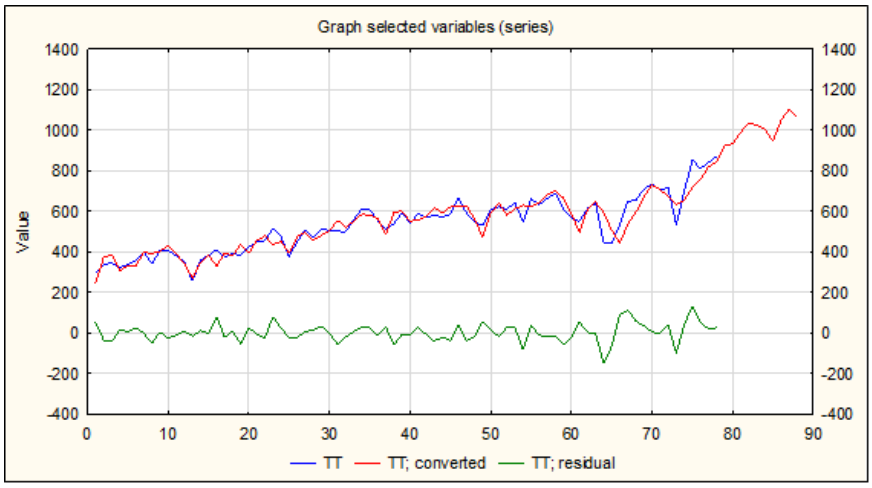


Figure 8. Visualization of source data and results obtained using the Holt-Winters exponential smoothing model

Source: Authors' calculations

The constructed models are applied to predict trade turnover volumes (variable TT) for the second half of 2021 (t =79, …, 84). The forecasting results and the relative forecasting errors (determined by formulas (6)) are shown in Table 6.

Table 6

Forecasts for the Holt-Winters models and actual data

Trade turnover (TT)		
Forecasts	Actual	Residuals
991.394	1011.4	0.019781
1038.266	1001.3	0.036918
1026.212	1019	0.007077
946.941	749.019	-
1050.057	-	-
1105.937	-	-

Source: Authors' calculations

The results presented in Table 6 show that the relative forecast errors for the TT variable according to the Holt-Winters exponential smoothing model are: for October 2021 – 1.9%; for November 2021 – 3.6%; for December 2021 – 0.7%.

The conducted studies enabled modelling and forecasting of the dynamics of trade turnover between Ukraine and Poland to build adequate models of the Box-Jenkins time series: SARIMA and Holt-Winters exponential smoothing. The results showed small relative forecast errors compared to actual data. Interestingly, modelling and forecasting exports and imports showed similar results.

Thus, it can be argued that Poland is the largest trading partner of Ukraine (among the EU countries). Significant is the steady increase in the volume of export-import operations between the countries after the Agreement on the Free Trade Zone between Ukraine and the EU (even despite the COVID-19 pandemic) and a stable positive trade balance between Ukraine and Poland.

6. DISCUSSION

The russian invasion of Ukraine is already leading to significant changes in the economies of European countries. This is primarily due to rising inflation, which high levels in Europe have previously caused concern among economists and ordinary citizens, and as a consequence of the purchasing power of households and businesses, which affects trade on domestic and international levels. The essence of inflation risks lies in the European Union's high dependence on energy imports from russia, limited by the imposition of sanctions against russia. In this context, this study is consistent with Mayr (Mayr, 2022), who analyses inflation expectations for EU countries from the effects of russian armed aggression against Ukraine, and Ikani (Ikani, 2019) in terms of russian intervention that uses "economic, informational and eventually military means", in the relations between the EU and Ukraine, which lead to changes in security, trade and other areas of regional cooperation.

Ukraine's trade reorientation from the russian direction towards the European Union, in particular, the nearest Poland, brought the two countries even closer, which allowed Ukrainians to count on substantial humanitarian and other assistance provided by the Republic of Poland to Ukraine and its citizens during the active phase of the Ukrainian-russian war of 2022. This is consistent with Jackson and Nei (Jackson & Nei, 2015), who show that "international trade induces peaceful and stable networks: trade increases the density of alliances so that countries are less vulnerable to attack". Without the help of Poland and other EU countries, the consequences for Ukraine, primarily humanitarian, would be more catastrophic.

At the same time, we observe that the increase in trade with Poland during the period under study did not lead to Ukraine's accession to NATO or the creation of another military alliance with Poland and the EU. This led to a lack of direct military assistance to Ukraine from the EU to fight against the aggressor. This is in line with the findings of Massoud and Magee "that more cooperation on political and military issues leads to greater trade between countries", but "the impact of overall cooperation on trade is larger than the effect of trade on Cooperation" (Massoud & Magee, 2012). Also, Kresin and Kresina (Kresin & Kresina 2021) believe that there is no reason to expect that European countries will be directly involved in restoring Ukraine's territorial integrity, which could be done militarily in the current circumstances.

The relevance of this study on the impact of russian aggression against Ukraine on Polish-Ukrainian trade relations is consistent with a study that shows in the example of Pakistan that interstate conflicts disrupt supply chains, damage transport corridors and require increased security measures, making trade more expensive (Naveed et al., 2021). Moreover, hostilities in the country reduce investor confidence in investing in export promotion projects. Therefore, forecasting the development of trade relations should be given with each change of factors that affect them. Especially as significant as military conflicts.

7. CONCLUSION

Several important conclusions can be drawn from the results of this study. First, if there was no russian aggression, the results of modelling could be reliably predicted by the models built in this work. Thus, the average projected trade turnover between Poland and Ukraine showed insignificant errors compared to the actual data for the last quarter of 2021, namely, for October, November and December 2021, according to the SARIMA model – 0.8%, 3.6% and 2.3%, respectively; for the Holt-Winters model – 1.9%, 3.6% and 0.7%, respectively. Considering expectations and the beginning of the russian military aggression, the average projected volume of Polish-Ukrainian trade for the first quarter of 2022 was reduced by 20% per month compared to the previous period. This forecast showed insignificant forecasting errors for January 2022 (compared to actual data): according to the SARIMA model – 3.8%; according to the Holt-Winters model – about 1%.

This study has some limitations. First, the study's findings are limited by the data on which the results are based. In particular, the results do not take into account significant changes in trade relations caused by martial law, cessation of activity by a significant number of enterprises and products' export in the temporarily occupied Ukrainian territory, mobilization of the economically active population and their involvement in military and other formations instead of their traditional activities, disruption of supply chains due to damage or destruction of transport and other infrastructure, redistribution of financial resources and flows to the needs of the Ukrainian army. At the same time, Poland has become the critical hub for the transfer to Ukraine of goods for various purposes, particularly humanitarian and military assistance from other countries. Taking into account the value of these goods in the trade volume would significantly change the performance of Polish-Ukrainian trade relations.

Further research should focus on the study of trade with other countries with which Ukraine has long and substantial trade relations and those who plan to start closer cooperation after the end of the war in Ukraine and its victory in the confrontation with russia. In future research, it is also advisable to add catastrophes to the factors influencing trade between countries, i.e. possible military actions in which they may be involved due to the aggressor's policy or changes in the security situation in the region or world.

In addition, the use of more sophisticated statistical methods, such as vector autoregressions or Granger cointegration time series (55), etc., to address the multilevel relationship between variables would allow considering available data on international trade relations more fully and deeply.

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DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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