Data Mining Method Application to Grain Export and Exchange Rates Co-Movement Under Incomplete Information

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Abstract

International commodity, financial and foreign exchange markets operate under conditions of uncertainty, incomplete or asymmetric information. Consequently, exchange rate dynamics is nonlinear and does not fit fundamental economic factors, and therefore cannot be sufficiently predictable. In addition, the export of goods depends on different factors that represent multidimensional data sets. Such complexity requires applying sophisticated analytical tools such as Data Mining to analyse and make reasonable management decisions under dynamic information.

Keywords

Data Mining, Exchange Rate, Export Revenues, Kohonen Map (Self-Organizing Map)

1 Introduction

Exchange rate volatility is one of the most important economic factors of global markets movements, national economies and firms' strategies nowadays. D. Lessard believes that "the sensitivity of a firm's profits to shifts in exchange rates may be greater than one for one" [1], while T. Ito, S. Koibuchi, K. Sato and J. Shimizu emphasise the significant influence of exchange rate volatility on both short term performance of the business and long term corporate strategies [2].

Furthermore, it plays a crucial role for developing countries and their leading export-oriented industries. Many Ukrainian researchers highlight the importance of the exchange rate for domestic export, especially agricultural ones (fig. 1), and argue that national currency devaluation is advantageous for domestic export [3; 4]. This issue became more important when the National Bank of Ukraine has switched to the flexible market exchange rates and inflation targeting regime. As a result, hryvnia met the significant loss of value during 2014-2021 with a few short-term strengthening. In this case, devaluation should increase export revenues by applying the competitive price of goods in foreign currency and increasing the hryvnia proceeds volume. However, this effect is not always to the full extent: devaluation affects exports differently depending on the price of goods elasticity; an increase of export receipts strengthens the national currency's exchange rate. Finally, due to devaluation, the domestic price of imported goods (fuel, components, imported raw materials) increases, which causes an increment of the final product price and is called Exchange Rate Pass-Through (ERPT). The ERPT is complex because it is nonlinear and is "higher in periods of small exchange rate changes" [4]. Consequently, O. Faryna indicates that "consumer prices in Ukraine are sensitive to small and extremely large NEER (nominal effective exchange rate) changes, while moderate changes are statistically insignificant" [4].

As shown in Fig. 1, the grain export revenues are overperforming the iron and steel export previously long dominated. Since the beginning of 2021, the world market prices of those commodities are going up. Grain export revenues constantly increasing, therefore, have a growing impact on the national economy and foreign currency market. Such a trend may continue in the

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medium-term due to the world market prices for grains and prospects for the grain crop increase in Ukraine.

Furthermore, export revenues are influenced by many factors that have an indirect or non-linear impact and therefore cannot be accurately predicted or quantified. Among them are the following: world demand and supply, consequently prices at international markets relative to domestic prices, transport costs, trade tariffs and taxes [6]; a macroeconomic situation in partner countries; supply and demand in the domestic market; terms of trade; export diversification; government policy; technological development; the competition in the global market and competitiveness; weather conditions and climate change; consumption structure and its changes, consumer preferences; stage of the economic cycle; political situation; information signals and news. It indicates a high level of uncertainty in the global environment and the need to make management decisions in conditions of incomplete or asymmetric information by processing significant amounts of information.

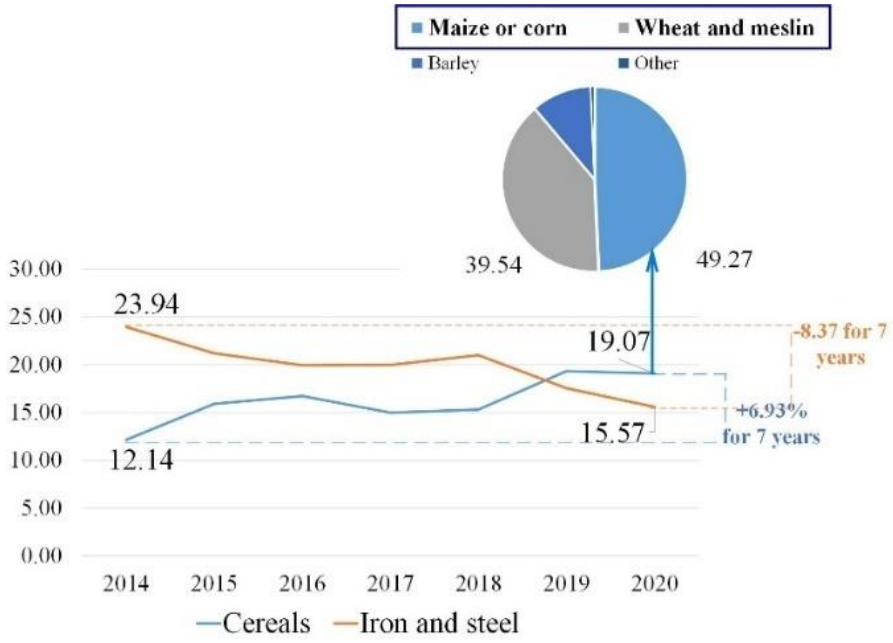


Figure 1: Structure and its changes of the first-rate export revenues of Ukraine during 2014-2020, % [5]

Therefore, the research aims to search for patterns of large data sets based on proceeds of grain export, exchange rate, and other factors using the data mining tool.

The study's hypothesis is a significant influence of the exchange rate on export proceeds for the export-oriented grain industry.

2 Related Works

International market processes are producing extremely complex and volatile data. Big data are considering as a large and unstructured data sets reflecting complex activities including economic and financial [7]. Data mining and machine learning are approaches to analyze large data with different techniques, such as “clustering variable models are prototype algorithm of unsupervised ML” [7].

Data mining includes functions of data clustering, data analysis, data visualization with application different techniques of multivariative adaptive regressions, vector regressions, Kohonen networks and others [8].

The last one presents a class of neural networks, considered an alternative to nonlinear multiple and logistic regression models since identifying relationships that classical regression models do not demonstrate. It creates opportunities for analysing the foreign exchange market since traditional

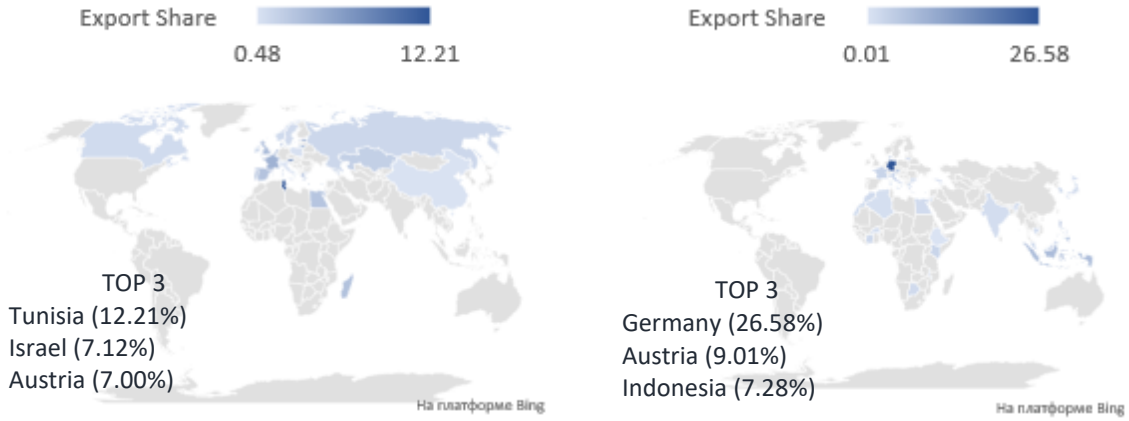
regression models have proven ineffective, especially in forecasting the exchange rate. For example, E. Zarutska et al. [9] and D. Kovalenko et al. [10] used Kohonen maps to study the financial risks of banks. Based on built maps for different periods and their changes, the authors investigated the systematic risk of the whole banking system and the risks of each bank individually [9].

Regarding the exchange market research, scientists have a propensity for using traditional econometric techniques as VAR self-regression vector model [11]; multivariate and time-varying univariate cointegration techniques [12]; Non-linear Autoregressive Distributed Lags (NARDL) model [13]. However, fuzzy and neural network methods steadily supplant classic econometric models in exchange market research. For instance, I. Strelchenko built a Kohonen map to find similar patterns in the dynamics of countries' exchange rates during the financial crisis of 2007-2009. As a result, data on exchange rate fluctuations of 65 countries was divided into 6 clusters characterising similar fluctuation trends course [14]. A. Kaminskyi et al. tested risk-return correspondence for cryptocurrencies as alternative investments through clustering cryptocurrencies by risk level using Kohonen maps. They investigated that it does not work for cryptocurrencies due to the crucial role of supply-demand factors and specifics of intangible assets [15].

However, the Kohonen map is usually used for clustering items into groups and analysing their division or dynamics [9; 10; 14]. In our opinion, it is a narrow way to use neural networks compare to identify the indirect cause-effect relationship as in the [15]. To test the influence of the exchange rate on export revenues, we decided to use the Kohonen map to a regression model to analyse the influence changes in different periods. In this case, our goal is not to improve the analysis method but use a new approach to study the exchange rate. We aim to analyse the change in the influence of factors and their significance on export earnings in various periods.

3 Data Description

We identified the top 3 importing countries of wheat and corn, as the primary goods of Ukrainian grain export, based on the geographical structure of export revenues. There are Germany, Austria and Indonesia for wheat exports, Tunisia, Israel and Austria for corn export (fig. 2).



Maize or Corn Wheat and Meslin

Figure 2: Geographic structure of grain exports, average during 2014-2020, % [5]

To study the relationship between the export revenues of grain and the exchange rate dynamics, we formed a sample of the main factors that potentially affect the dynamics of domestic exports. Fourteen macroeconomic indicators represent these factors. We divided them into three groups: foreign exchange rates, prices at the world market through the biggest world commodities exchanges, and conditions of the importing markets based on producer price indices, PPI in all import countries (fig. 3).

To analyse prices of the world markets, we chose futures prices of the world's largest exchanges

specialising in selling these goods, namely London Wheat Futures and US Wheat Contract, US Corn Futures. For wheat and meslin export revenues, we used single currency crosses EUR/USD, IDR/USD, and UAH/USD; prices of London Wheat Futures and US Wheat Contract; producer prices indices of Austria, Germany, Indonesia. To test our hypothesis for corn export revenues, we used currency crosses USD/TND, EUR/USD, ILS/USD, and UAH/USD; price of US Corn Futures; producer price indices of Israel, Tunisia, and Austria.

We chose the period between 2014 and January 2021; due to the start of the hryvnia devaluation in the II quarter of 2014. Eighty-five periods were analysed. Thus, the initial data consists of 1,190 observations (14 factors * 85 periods).

We used the statistical databases Investing.com, OECD database, International Trade Centre, and Trading Economics [5; 16; 17; 18].

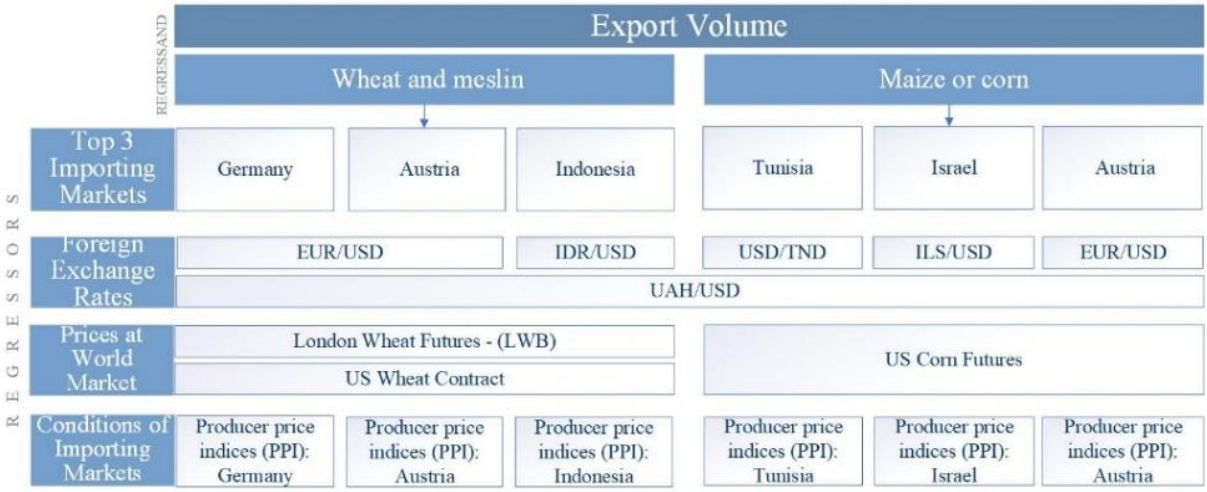


Figure 3: Factors influencing the export of wheat and corn in case of selected countries

4 Methodology

To verify the relation of wheat and corn export revenues and the exchange rate, we used a neural network, namely a competitive network with unsupervised learning - Kohonen Map or Self-Organizing Map (SOM) in Deductor Studio Academic. This method uses the Winner Take All (WTA) algorithm. Accordingly, winning neurons with the minimum scalar product of the connection weights and the input vector are determined at each stage of training. Kohonen Maps are built on a single layer of neurons, organised as a two-dimensional matrix [14]:

$$w_p(t) = w_p(t-1) + \eta * \Lambda * [x_p(t) - w_p(t-1)] \quad (1)$$

where $w_p(t-1), w_p(t)$– parameter number p of the Kohonen map neuron before and after correction, respectively;

$x_p(t)$–element number p of the input data vector is presented at the t training step;

η– the learning rate coefficient (0<η< 1),which changes in the process of neural networkself-organisation;

Λ–the neighbourhood function between the given neuron and the winning neuron.

This method divides the original sample of 1,190 observations into groups according to certain similarities –clusters. The clusters will describe the periods when the export revenues were homogeneous. It will test the hypothesis of how and whether the exchange rate affects export earnings: if during the period of the hryvnia devaluation, the value of this factor on export earnings was high, then we accept the hypothesis of the study and confirm the opinion of Ukrainian scientists on the positive impact of devaluation on Ukrainian exports; if the significance of the factor is low or does not show any connection with the dynamics of revenues, which means that the factors of the world market affect the export revenues.

5 Results

5.1 Analysis of the Learning Quality of the Kohonen Network

The unsupervised neural network was trained separately for wheat and corn export revenues, resulting in 4 clusters each (fig. 4).

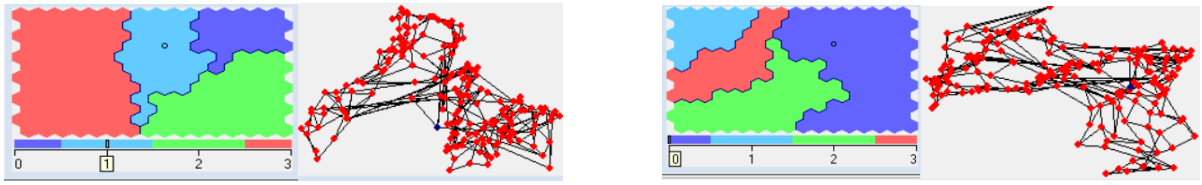


Figure 4: Learning Outcomes of Kohonen Maps

The distance matrix indicates a lower level of differences between neurons for maize (corn) compare to wheat and meslin export, meaning that maize (corn) export is more expressly driven by the factors rather than wheat export. The quantisation error matrix proves that the Kohonen network is well trained – the average distance to the centre is low, which means that neurons are close to it in both cases. It can distribute the grain export revenues and the most important factors into groups clearly (fig. 5).

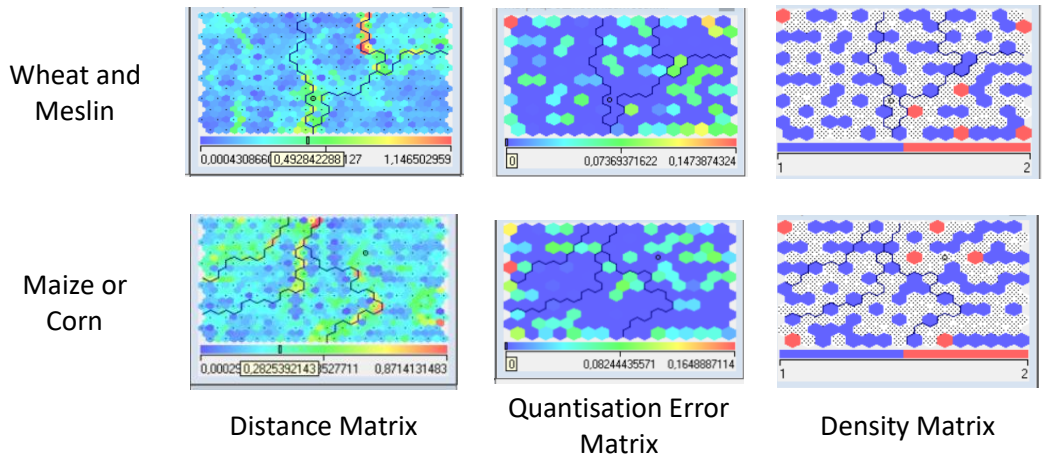


Figure 5: Assessment of the clusters' quality

However, the density matrix showed that many objects did not fall into the cells indicating that these observations have different properties and are unlike others. In other words, export earnings are influenced by factors that are random or probabilistic. Notwithstanding, the overall quality of maps is good; we will use them for further analysis under incomplete information.

5.2 Analysis of Wheat Export Revenues

It is crucial to analyse the similarities and interrelationships of clusters to explain the dynamics of the analysed indicators (Fig. 6). Cluster linkages for wheat export revenues showed strong linkages (relative to existing) between Cluster 0 and Cluster 2, Cluster 1 and Cluster 3, Cluster 1 and Cluster 2. However, the absolute degree of these relationships is low; the correlation coefficients are less than 75%. It indicates the lack of fundamental relations in wheat exports dynamics and the dominant role

of probabilistic factors.

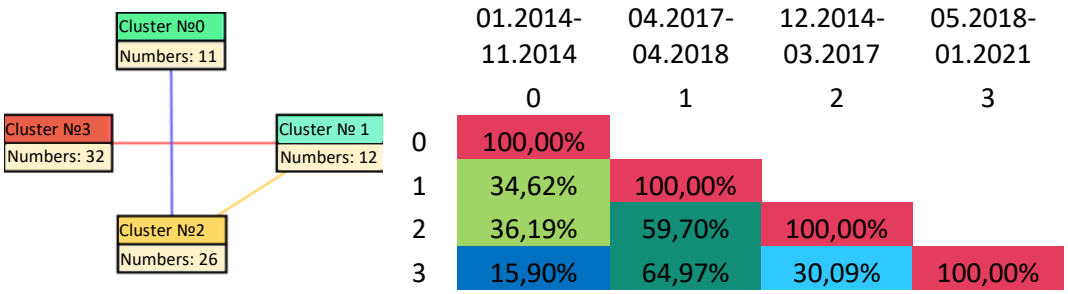


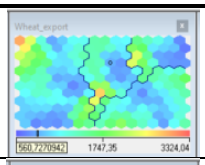
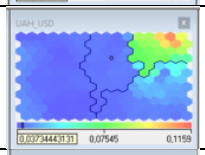
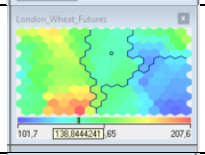
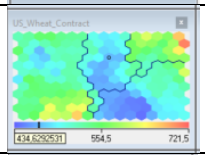
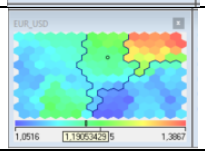
Figure 6: Distribution of clusters and their similarity (wheat export revenues)

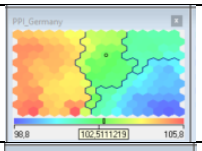
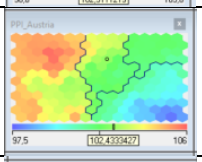
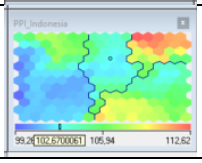
Let us analyse the weight of factors in clusters (Table 1). First of all, we note that Cluster 0 covers the economic and political crisis in Ukraine. The rapid growth of the risk premium and the devaluation of the national currency's exchange rate reflected this period. Therefore, all executive authorities and the National Bank of Ukraine aimed at currency targeting. Consequently, the weight of the exchange rates of the hryvnia and the euro against the US dollar is 100%.

Cluster 2 covers the period of hryvnia's free exchange rate and the NBU's transition to inflation targeting. According to fundamental economic laws, the devaluation of the national currency, which peaked at the beginning of 2015, should have increased exports due to improving price competitiveness at international markets.

Table 1

Cluster Profiles of Wheat Export Revenues

Kohonen Maps	Factors and their significance on export revenue in %	Clusters			
		0	1	2	3
		01.01.2014-01.11.2014	01.04.2017-01.04.2018	01.12.2014-01.03.2017	01.05.2018-01.01.2021
	Wheat Export	42.2%	14.9%	5.3.%	17.4%
	UAH/USD	100%	89.7%	62.5%	100%
	London Wheat Futures	42.9%	18.8%	100%	100%
	US Wheat Contract	100%	98.9%	98.7%	95%
	EUR/USD	100%	68.1%	99.9%	91.9%

	PPI Germany	87.8%	18.5%	100%	100%
	PPI Austria	67.2%	25.4%	100%	100%
	PPI Indonesia	100%	91.2%	97.6%	100%

However, the significance of the exchange rate during this period is the lowest among other clusters and amounts to 62.5%. It can be explained by the low elasticity of traditional Ukrainian export goods, namely raw materials and goods with a low degree of processing. The world demand for these goods is secondary and depends, first of all, on final consumption goods industries and not on the world market prices. Based on the devaluation, the current account surplus was achieved in 2015 [19], but due to a decrease in imports and optimisation of the consumption structure in the domestic market, rather than the expected increase in export revenues.

The factor "US Wheat Contract", due to global supply and demand, and PPI in Indonesia are consistently significant factors in wheat export revenues. The second factor can be explained by the fact that Indonesia is a developing country, and therefore the production system is highly dependent on the macroeconomic environment.

5.3 Analysis of Corn Export Revenues

Analysis of the clusters based on corn export revenues showed a high level of clusters dependence among themselves; in particular, the correlation coefficient of Clusters 2 and 3 is 70.12% (Fig. 7).

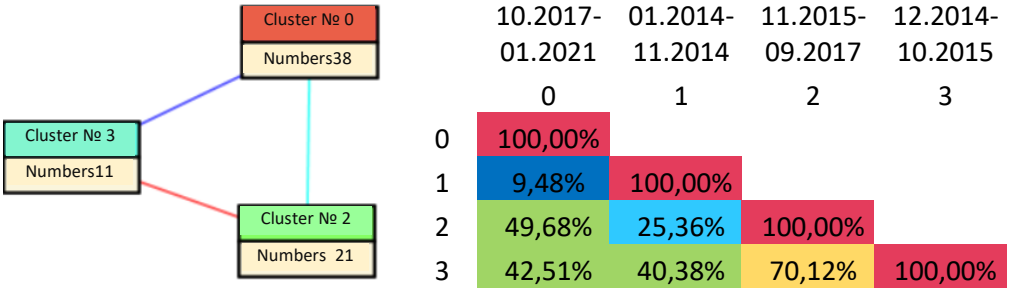


Figure 7: Distribution of clusters and their similarity (using the example of corn revenues) *

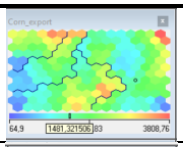
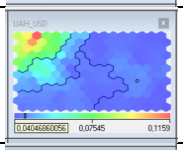
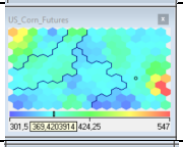
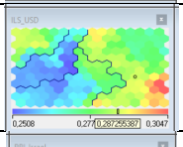
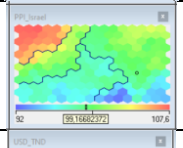
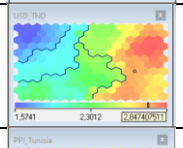
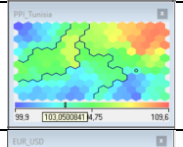
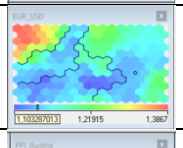
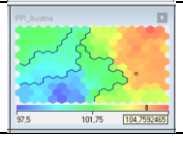
* the figure shows clusters connected with each other by strong relations, cluster No. 1 does not correlate with other clusters

We should note that all the factors have an extremely high level of significance in all clusters, except in some cases: the hryvnia exchange rate during December 2014 - October 2015 and the price of US Corn Futures during October 2017- January 2021 (table 2). Nevertheless, corn export revenues are significantly dependent on the macroeconomic situation in the importing countries, namely the exchange rate and producer prices in Austria, Tunisia and Israel.

Table 2

Cluster Profiles of Corn Export Revenues

Kohonen Maps	Factors and their	Clusters

	significance on export revenue in %	0 01.10.2017-01.01.2021	1 01.01.2014-01.11.2014	2 01.11.2015-01.09.2017	3 01.12.2014-01.10.2015
	Corn Export	68%	90.5%	26.4%	18.8%
	UAH/USD	100%	100%	93.7%	38.1%
	US Corn Futures	7.8%	99.4%	95.9	10.2
	ILS/USD	100%	74%	99.2%	100%
	PPI Israel	83.8%	100%	99.8%	76.6%
	USD/TND	100%	100%	87.3%	99.9%
	PPI Tunisia	98.1%	99.7%	99%	82.9%
	EUR/USD	47.3%	100%	99.5%	89.5%
	PPI Austria	100%	67.2%	100%	99.4%

5.4 Analysis of Grain Export and Exchange Rates Co-Movement

Analysis of the relationship between grain export revenues and the exchange rate stated that the fundamental relations between devaluation and an increase in export revenues are not justified during periods of the most incredible devaluation of the hryvnia - the significance of the exchange rate is 38.1% in December 2014 and October 2015 (corn) and 62.5% during December 2014 and March 2017 (wheat). It indicates that external factors have the most significant influence on export revenues: the macroeconomic situation of the importing countries and the world markets conditions.

In addition, export revenues are significantly influenced by factors such as the seasonality of the industry, and, therefore, the seasonality of cash flows, storage technologies and delivery methods, supply and demand in the domestic and world markets, weather and, as a result, crop yields in the countries of exporters and importers (if it has own production), preferences and changes in the structure of consumption in foreign markets, the macroeconomic and political situation of the primary exporting countries, the stage of the economic cycle of the international economy. As a result, the

value of export revenues in clusters is deficient compared to other factors; respectively, we can conclude that their dynamics is unstable and depends on factors that are difficult or impossible to quantify and predict.

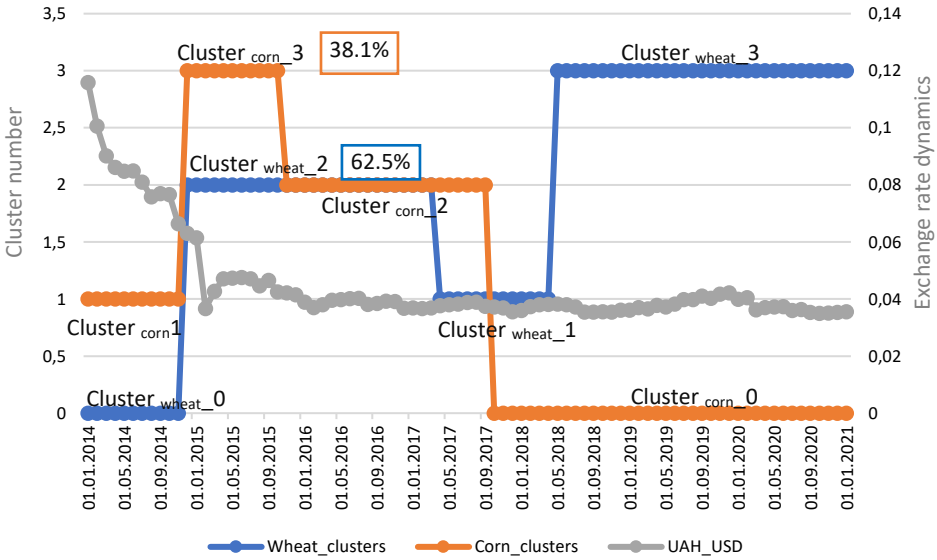


Figure 8: Co-Movements of Grain Export and Hryvnia Exchange Rate

For instance, the increase in prices for all raw materials in early 2021 is unpredictable. This increase responds to the global economic recovery after the COVID-19 pandemic due to the "soft" money policy used by the governments of most countries, and that led to inflation. Moreover, the economic situation in China, which is one of the largest importers of grain in the world, has an indirect impact on Ukraine's export earnings for several reasons. Firstly, an increase in well-being contributes to better quality and, consequently, higher prices of consumed goods. Secondly, the consumption structure transformed and included traditional European goods such as coffee, cocoa bean products, sunflower oil, and corn. Thirdly, the forecast of the worst yield stimulates the government to increase stocks. Another factor influencing the volume of the grain trade in the world market was unfavourable weather conditions in the leading countries of corn export - France and Brazil [20], winter wheat in the USA, which will continue to pressure the agricultural industry due to global climate change and the need to change specialisation in the production of the agricultural goods. It is also impossible to ignore the dynamics of prices of fuel resources, primarily oil, which significantly affect the world market of raw materials and form a significant foreign exchange component in the cost of domestic products.

The exchange rate volatility complicates the analysis because its dynamics do not precisely rely on fundamental economic factors. In particular, in 2020, a behavioural factor pressured the hryvnia more than the macroeconomic situation.

As a result, export revenues are significantly influenced by prices on international commodity markets but not the exchange rate. The reason is that devaluation increases the value of imported components and servicing of loans in foreign currency. This part is 50-70% of costs on average. The change in the 1% affects the EBITDA profitability of exporters by 0.2% in the same period [21].

The high significance of the exchange rate in other periods we explain by the stabilisation of the foreign exchange market and the moderate volatility. Moreover, its dynamics and directly correlate with the general macroeconomic situation in Ukraine.

6 Conclusions

As a result of the study, we designed and built neural networks of the Kohonen maps to investigate the relationship between grain export revenues and the exchange rate. Each network consists of 4

neurons (according to the number of classification clusters), and a possible learning error is 10%.

We used the neural network to assess the mutual influence of the dynamics of the national currency exchange rate and the export revenues of wheat and corn. The analysis showed that the fundamental assumptions about an increase in export revenues due to the devaluation of the national currency during the periods of the most significant depreciation of the hryvnia do not come true - the significance coefficient of the exchange rate is 38.1% in December 2014 and October 2015 (corn) and 62.5% during December 2014 and March 2017 (wheat). On the other hand, a high level of dependence relates to indicators that describe the macroeconomic situation of importing countries and the world markets conditions. Kohonen maps allowed us to identify the significant factors influencing export earnings in different periods, in contrast to the use of regression, it will help to use adaptive management methods at different stages of the economic cycle.

Thus, to make effective management decisions, an enterprise should analyse various factors directly or indirectly affect export revenues and profitability. This analysis should be conducted using the Data Mining methods, considering the likelihood of factors under incomplete or asymmetric information.

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