LITTERA SCRIPTA

Economics

Management

Corporate Finance

Finance and Valuation

2/2025

VŠTE

Littera Scripta

(Economics, Management, Corporate Finance, Finance and Valuation)

Ing. Jakub HORÁK, MBA, PhD. (Editor-in-chief)

Address Editor:

Institute of Technology and Business in České Budějovice

Okružní 517/10

370 01 České Budějovice, Czech Republic

Tel.: +420 387 842 183

e-mail: journal@littera-scripta.com

ISSN 1805-9112 (Online)

Date of issue: December 2025

Periodicity: Twice a year Since 2010

The Journal is indexed in:

- ERIH PLUS (European Reference Index for the Humanities and Social Sciences) – in 2015
- CEJSH (Central European Journal of Social Sciences and Humanities) – in 2015
- EZB (Elektronische Zeitschriftenbibliothek) – in 2017
- GOOGLE SCHOLAR – in 2017
- DOAJ (Directory of Open Access Journals) – in 2019

Content

The Impact of the War in Ukraine on the Development of Wheat and Rye Prices: An Analysis for the Period 2018-2024

Beata Kaplanová[1], Vilém Kovač[2], Michal Ištok[3]

[1,2] Institute of Technology and Business in České Budějovice, Faculty of Corporate Strategy
[3] Matej Bel University in Banska Bystrica, Faculty of Economics

Abstract

The aim of the work is to assess the long-term development of wheat and rye prices in the period from 1 December 2018 to 1 April 2024 and to analyse the impact of the war in Ukraine on these prices. Analyses of the price development of these commodities are important for assessing economic stability and food availability. The prices are obtained by content analysis and then plotted in graphs. Using linear regression, it was found that the prices were not time dependent, Also, the prices of both commodities are found to be stable and very similar until the period of war in Ukraine. The latter had a significant impact on wheat and rye prices, with prices doubling after the start of the conflict. Subsequently, prices started to fall again, indicating market adaptation to the new conditions. Limitations of the study include the limited scope of the available data and the potential bias of the results due to the effects of other factors. Further research would benefit from including an extension of the analysis to include other influencing factors and increasing the frequency of data collection for more detailed analysis.

Keywords: Wheat, rye, price development, linear regression, war in Ukraine.

Introduction

Agriculture occupies a key position within the economic framework, as it provides a range of benefits for local communities. Its impact can be observed through various aspects, such as the provision of employment opportunities, income generation, and improvements in living standards, including ensuring food security (Mensah, 2023). For example, Fu et al.

(2023) argue that food security is highly important for all countries. In this context, agricultural price insurance represents an important tool for maintaining food security.

The stabilization of agricultural product prices is a key element in supporting social and economic development. Agriculture forms a fundamental pillar for many societies and economies; therefore, maintaining stable agricultural prices is essential for sustaining prosperity. Price fluctuations may occur in agriculture, and it is important to identify them, as they have a crucial impact on policy formulation and decision-making in agricultural production. These insights help to establish measures and strategies that influence agricultural prices, which in turn significantly affect agricultural markets and the overall economy (Wang et al., 2022).

Wheat is globally considered the most important cereal crop. It has enormous economic significance, as it is used for the production of bread, bakery products, and flour for households, and also serves as feed for livestock. Wheat is also utilized in healthcare due to its medicinal properties and nutritional composition (Ammar et al., 2023). This is supported by Gutierrez (2017), who states that wheat is globally significant for consumption, as it provides 20% of the world's calories and nutrients.

Rye is a very important cereal crop in many parts of Europe, and rye breeders are currently addressing the limited pool of genetic resources (Monteiro et al., 2016). It is also frequently used as a cover crop to improve soil health and as part of integrated weed management programs (Vollmer et al., 2020).

Rye plays an important agronomic, nutritional, and social role throughout human civilization. Over the past 50 years, rye grain yields have increased, though not sufficiently to offset the decline in cultivated area needed to maintain production. In this context, hybrid rye has significant potential due to its high yield performance and greater resistance to climate variability. The production area of hybrid rye has been increasing in recent years and is expected to continue growing. In the past decade, potential new markets for rye biomass have included applications such as biogas production and environmental sustainability initiatives. Although rye genomics lags behind other cereal crops, it has significantly contributed to understanding the evolution of the grass family through comparative genomic analyses. Over the past 50 years, advances in rye genomics and breeding have led to new and exciting research areas, particularly hybrid rye varieties, which outperform conventional synthetic varieties by 20–30% in both biomass and grain yield.

While rye may be considered a less important crop in terms of production, its contributions to cereal genomics have been substantial (Korzun et al., 2021).

The aim of this study is to evaluate the long-term development of wheat and rye prices in the period from December 1, 2018 to April 1, 2024, and to analyze the impact of the war in Ukraine on these prices.

In connection with this objective, the following research questions are defined:

RQ1: How did the prices of wheat and rye develop in the period from December 1, 2018 to April 1, 2024?

Answering this question provides an overview of how wheat prices in the Czech Republic evolved during the observed period.

RQ2: How did the war in Ukraine affect prices?

Answering this research question provides insight into the development of wheat and rye prices in the Czech Republic during the period from October 1, 2021 to March 1, 2024, and determines whether the war in Ukraine influenced these prices.

Data and methods

Data

To answer the first research question, it is necessary to obtain the prices of wheat and rye as of the first day of each month from December 1, 2018 to April 1, 2024. The data will be collected through content analysis from the websites of the State Agricultural Intervention Fund and the Czech Statistical Office. The data will then be recorded in tables using Microsoft Excel, and subsequently visualized in graphs.

For the second research question (RQ2), which focuses on the impact of the war in Ukraine on prices, the same approach will be applied as for the first research question, with the only difference being the selected time period. The observed period will be from October 1, 2021 to March 1, 2024.

Methods

To answer the first research question concerning the development of wheat and rye prices in the period from December 1, 2018 to April 30, 2024, the method of linear regression will be used. This method allows for the mathematical expression of the relationship between time and the prices of these commodities. The regression coefficients and their errors will be calculated using Microsoft Excel through the Data Analysis tool, where regression will be selected. The most important outputs will be the p-values, which indicate whether the effect is statistically significant, and the R^2 value, which determines how well the model explains the variability in commodity prices.

It is also possible to use the method of least squares to determine a linear function, which effectively describes the relationship between time and price. This linear regression model has the following form (UJEP, 2024):

$$y = k * x + q \tag{1}$$

where:

y – price of wheat or rye,

x – time index,

k – regression coefficient representing the rate of price change,

q – regression coefficient representing the initial price.

The regression coefficients k and q are calculated using the following formulas (UJEP, 2024):

$$k = \frac{n * (\sum_{i=1}^{n} x_i y_i) - (\sum_{i=1}^{n} x_i) * (\sum_{i=1}^{n} y_i)}{n * (\sum_{i=1}^{n} x_i^2) - (\sum_{i=1}^{n} x_i)} \tag{2}$$

$$q = \frac{(\sum_{i=1}^{n} x_i^2) * (\sum_{i=1}^{n} y_i) - (\sum_{i=1}^{n} x_i) * (\sum_{i=1}^{n} x_i y_i)}{n * (\sum_{i=1}^{n} x_i^2) - (\sum_{i=1}^{n} x_i)} \tag{3}$$

The correlation coefficient, whose value lies within the interval ⟨-1, 1⟩, will be used to determine the degree of linear dependence between time and the prices of wheat and rye. The closer the result is to 1 or -1, the stronger the dependence.

Based on the estimated regression coefficients k and q, it is possible to determine the expected development of prices. The formula for its calculation is as follows (UJEP, 2024):

$$r_{xy} = \frac{\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n} (x_i - \bar{x})^2 \sum_{i=1}^{n} (y_i - \bar{y})^2}} \tag{4}$$

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \qquad \bar{y} = \frac{\sum_{i=1}^{n} y_i}{n} \tag{5}$$

Furthermore, the standard errors of the regression coefficients k and q would be calculated. These intervals make it possible to express the uncertainty of the estimates and provide a more accurate picture of the development of wheat and rye prices. The formulas for their calculation are as follows (UJEP, 2024):

$$\sigma_k = \sqrt{\frac{S_0}{(n-2)*\left[\sum_{i=1}^{n} x_i^2 - \frac{1}{n}*(\sum_{i=1}^{n} x_i)^2\right]}} \qquad \sigma_q = \sqrt{\frac{S_0*\frac{1}{n}*\sum_{i=1}^{n} x_i^2}{(n-2)*\left[\sum_{i=1}^{n} x_i^2 - \frac{1}{n}*(\sum_{i=1}^{n} x_i)^2\right]}} \tag{6}$$

$$S_0 = \left(\sum_{i=1}^{n} y_i^2\right) - \frac{1}{n} * (\sum_{i=1}^{n} y_i)^2 - k * \left[\sum_{i=1}^{n} x_i\, y_i - \frac{1}{n} * \left(\sum_{i=1}^{n} x_i\right) * \left(\sum_{i=1}^{n} y_i\right)\right] \tag{7}$$

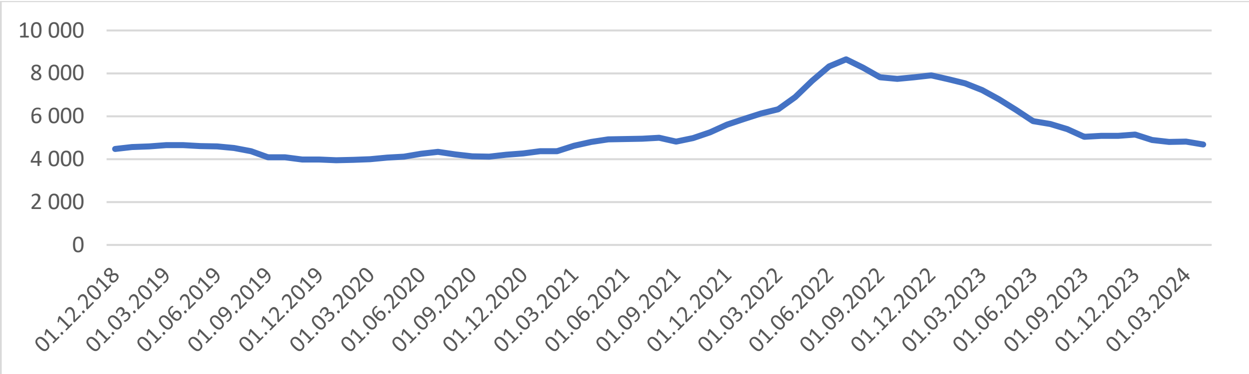
The confidence interval of the estimated regression coefficients, and thus their accuracy, depends on these deviations and the chosen probability level P. The Student’s t-coefficient t_p, (n−1) has parameters n−1 and P = 95% (UJEP, 2024).

To answer the third research question, the same procedure will be applied using Microsoft Excel; however, only wheat and rye prices for each month in the period from October 1, 2021 to March 1, 2024 will be used.

Results

After obtaining the prices of food wheat and rye from data analysis provided by the State Agricultural Intervention Fund, where prices are expressed in Czech crowns per ton, the focus was placed on the period from December 1, 2018 to April 1, 2024. The data are collected as of the first day of each month. The prices are then recorded in tables, and these tables are subsequently used to create graphs for visualizing price developments over the observed period.

Graph 1: Development of Food Wheat Prices [CZK/t], 01/12/2018–01/04/2024

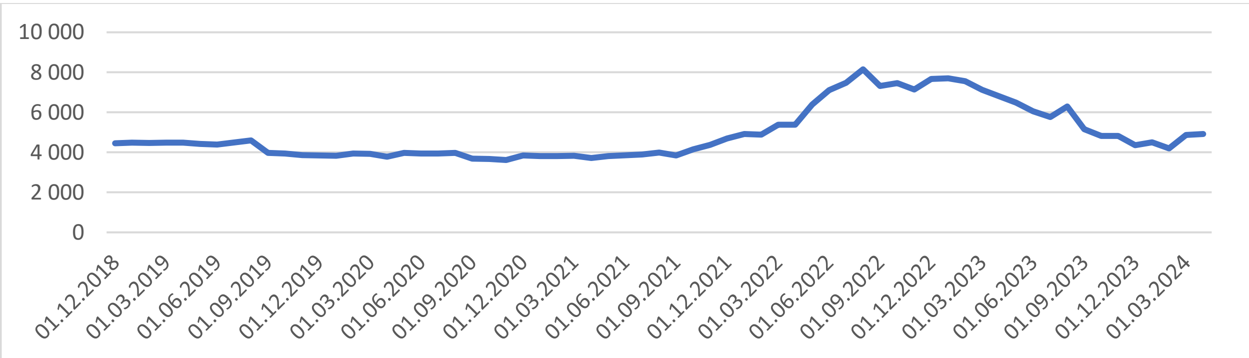


Source: Author's own elaboration based on (State Agricultural Intervention Fund, 2024).

Graph 1 shows the development of food wheat prices over the observed period. The average price of this commodity is 5,342 CZK/t. The lowest price was recorded on January 1, 2020, at 3,949 CZK/t, which represents a significant difference compared to the highest recorded price of 8,654 CZK/t on July 1, 2022 – more than double the lowest value.

It is evident from Graph 1 that the price developed relatively steadily until 2021, when it first exceeded 5,000 CZK/t at the end of the year. From that point onward, the price continued to increase. At the beginning of 2022, the increase became significantly steeper; however, from 2023 onward, the price of the commodity began to decline again and is now almost at the same level as before 2021.

Graph 2: Development of Food Rye Prices [CZK/t], 01/12/2018–01/04/2024



Source: Author's own elaboration based on (State Agricultural Intervention Fund, 2024).

Graph 2 illustrates the development of the price per ton of food rye over the same period. The average price is slightly lower than that of food wheat, amounting to 4,955 CZK/t. The lowest price was recorded on November 1, 2020, at 3,617 CZK/t.

A significant increase in the price of this commodity occurred a few months later than in the case of wheat, specifically in March 2022. The price rose sharply until August 2022 and then began to gradually decline. However, it returned to its original level only in October 2023, and since then, the price has not exceeded 5,000 CZK/t.

During this period of price fluctuation, the highest price of food rye was recorded at 8,150 CZK/t, representing an even larger increase than in the case of food wheat.

Figure 1: Regression of Food Wheat and Rye Prices for the Period 01/12/2018–01/04/2024

Regression statistics	
Multiple R	0,560094439
R Square	0,31370578
Adjust Square R	0,302636519
Standard Error values	1128,45394
Observations	64

ANOVA

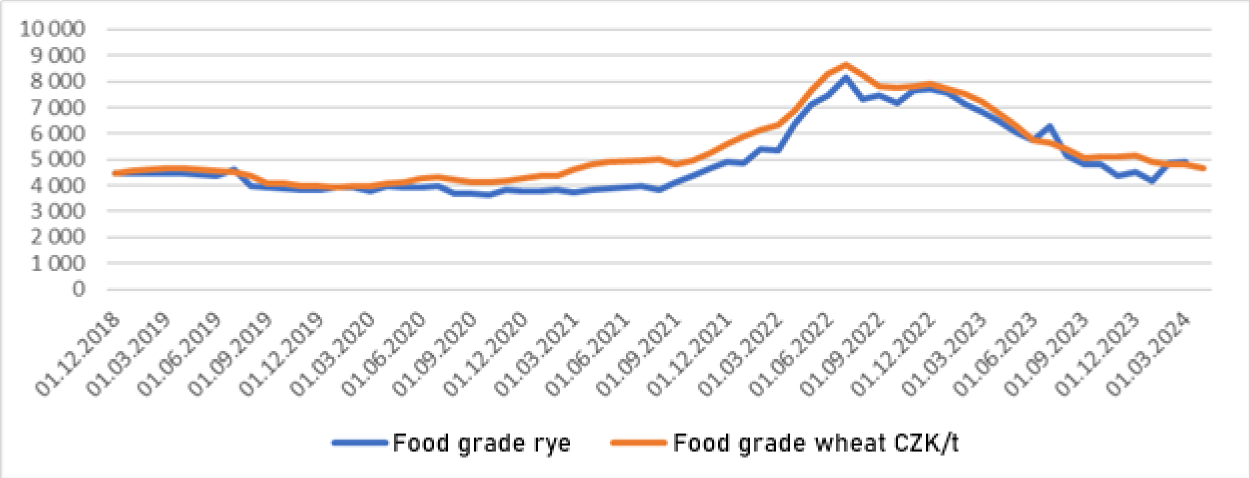
	Variance	*SS*	*MS*	*F*	*Significance F*
Regresion	1	36088725,45	36088725,45	28,34026257	1,49201E-06
Residual	62	78951314,3	1273408,295		
Total	63	115040039,8			

	Coeffiecients	*Standard error*	*t Stat*	*Value P*	*Lower 95%*	*Higher 95%*	*Lower 95,0%*	*Higher 95,0%*
Limit	-52612,01034	10887,23368	-4,832449811	9,23361E-06	-74375,28036	-30848,7	-74375,3	-30848,7
Time	1,304978396	0,245132778	5,323557323	1,49201E-06	0,814964955	1,794992	0,814965	1,794992

Source: Author's own elaboration based on (State Agricultural Intervention Fund, 2024).

After listing the prices of food wheat and rye for each month from December 1, 2018 to March 1, 2024, the data analysis showed that the model explains 56% of the variability in commodity prices, and the p-value was 0.000009234. Therefore, price is not statistically dependent on the time period, as there are other factors that influence it much more significantly.

Graph 3: Comparison of the Development of Food Wheat and Rye Prices [CZK/t], 01/12/2018–01/03/2024

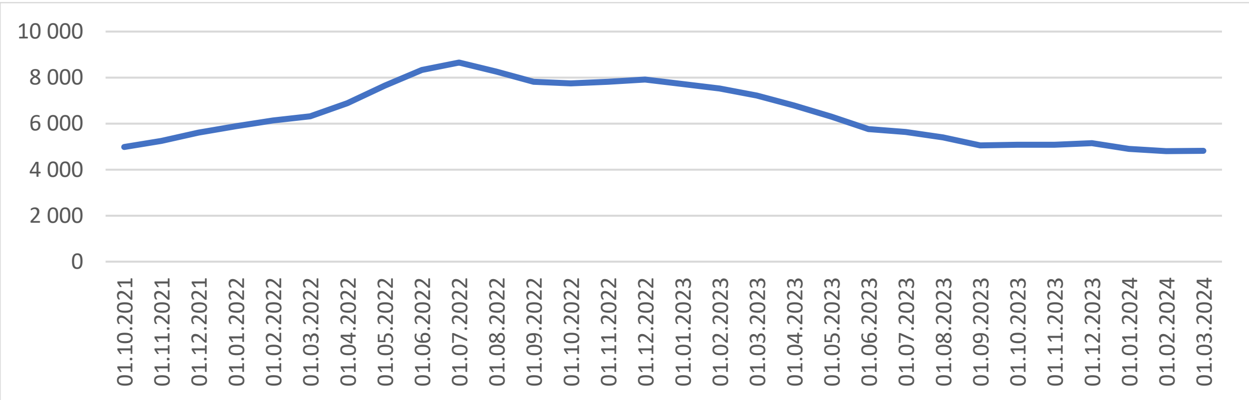


Source: Author's own elaboration based on (State Agricultural Intervention Fund, 2024).

Graph 3 shows a very similar price development for these commodities. Food wheat generally reaches higher prices, and the price increase occurred a few months earlier than in the case of food rye. In the case of rye, more pronounced price fluctuations can also be observed.

Graphs 4 and 5 illustrate the development of food wheat and rye prices in Czech crowns per ton (CZK/t) over different time periods. Both graphs cover the period from October 1, 2021 to March 1, 2024, which includes the onset of the war in Ukraine in February 2022.

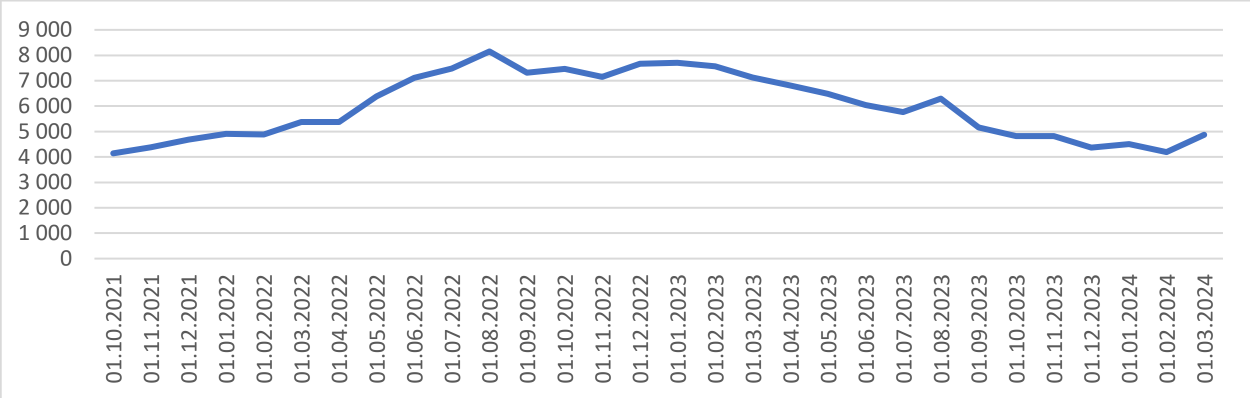
Graph 4: Development of Food Wheat Prices [CZK/t], 01/10/2021–01/03/2024



Source: Author's own elaboration based on (State Agricultural Intervention Fund, 2024).

In the case of food wheat, illustrated in Graph 4, the price starts just below 5,000 CZK/t and gradually increases until February 2022. The price then peaks in June 2022 at nearly 9,000 CZK/t. From the beginning of 2023, however, the price gradually declines and stabilizes around 5,000 CZK/t at the beginning of 2024, which is a level comparable to prices before 2021.

Graph 5: Development of Food Rye Prices [CZK/t], 01/10/2021–01/03/2024



Source: Author's own elaboration based on (State Agricultural Intervention Fund, 2024).

Graph 5, which illustrates rye prices, shows a similar trend. The price of rye starts at around 4,000 CZK/t and rises to approximately 5,000 CZK/t by the beginning of 2022. From March 2022, there is also a sharp increase in price, reaching a peak in June 2022 at around 8,000 CZK/t.

After June 2022, rye prices fluctuate between 7,000 and 8,000 CZK/t, and from the beginning of 2023, they gradually decline. By the end of the observed period, the price once again resembles the level recorded before 2021.

Discussion

RQ1: Development of wheat and rye prices in the period 01/12/2018–01/04/2024

The analysis of food wheat and rye price development over the period from December 1, 2018 to April 1, 2024 showed that the model explains 56% of the variability in commodity prices and that prices are not statistically dependent on the time period, as they are influenced more strongly by other factors. The analysis also revealed several important trends.

The price of food wheat remained relatively stable until 2021, when it began to gradually increase. A more significant rise was observed at the beginning of 2022, with a peak in June 2022, when the price reached nearly 9,000 CZK/t. This was followed by a gradual decline, and by the end of the observed period, the price stabilized at around 5,000 CZK/t. This development suggests that the wheat market was influenced by various factors, including global economic conditions and specific events.

Similarly, the price of food rye remained stable until the beginning of 2022. A sharp increase was recorded from March 2022, with a peak in June 2022 at around 8,000 CZK/t. After this peak, the price fluctuated between 7,000 and 8,000 CZK/t and began to gradually decline from the beginning of 2023. By the end of the observed period, the price stabilized at approximately 4,500 CZK/t. This trend indicates that the rye market responded to similar factors as the wheat market, although price fluctuations were somewhat more pronounced.

Simotová et al. (2023) analyzed wheat and rapeseed prices for the period 2017–2022 and reached similar conclusions, namely that the prices of these commodities were variable over time, without strong long-term trends or clear seasonal patterns.

RQ2: How did the war in Ukraine affect prices?

The war in Ukraine, which began in February 2022, had a significant impact on the prices of food wheat and rye. Immediately after the outbreak of the conflict, a dramatic increase in prices of both commodities was observed. Ukraine is one of the largest exporters of wheat and rye, and disruptions in its supply had an immediate and substantial effect on prices.

Wheat prices began to rise sharply from February 2022 and peaked in June 2022. This rapid increase can be directly linked to supply disruptions from Ukraine and subsequent concerns about global availability of this commodity. After reaching the peak, prices gradually declined, which may indicate that the market adapted to new conditions, for example through increased production in other regions or the identification of alternative suppliers.

Rye prices followed a similar pattern to wheat prices, with a sharp increase from March 2022 and a peak in June 2022. As with wheat, this increase can be attributed to disruptions in production and exports caused by the war in Ukraine. After reaching the peak, prices fluctuated and then began to decline, suggesting a similar market adaptation as in the case of wheat.

The results clearly show that the war in Ukraine had a significant and immediate impact on the prices of food wheat and rye. The sharp increase in prices immediately after the outbreak of the conflict reflects supply disruptions and global concerns regarding the availability of these commodities. The subsequent decline in prices suggests that the market gradually adapted to new conditions, which may have included increased production in other regions or the identification of alternative suppliers. By the end of the observed period, prices stabilized at levels comparable to those before the war, indicating the market's ability to adjust and restore equilibrium even during global crises.

Martin and Minot (2022) reached similar conclusions in their study on the development of agricultural commodity prices, confirming that food crises in Ukraine doubled the overall increase in global wheat prices.

Conclusion

The aim of this study was to evaluate the long-term development of food wheat and rye prices in the period from December 1, 2018 to April 1, 2024 and to analyze the impact of the war in Ukraine on these prices. These objectives were successfully achieved.

The analysis of commodity price development over the observed period from December 2018 to April 2024 revealed that the model explains 56% of the variability in commodity prices and that prices are not statistically dependent solely on the time period. This indicates that, in addition to time trends, there are other variables that significantly influence these prices, such as economic conditions or climatic factors.

Significant trends in the data showed that the prices of food wheat and rye were relatively stable until the end of 2021, a period characterized by slight fluctuations without major volatility. From the end of 2021, however, prices began to gradually increase. This increase was not immediate. A sharp rise in prices was observed from March 2022, which can be primarily attributed to the impact of the war in Ukraine. The conflict had a direct effect on supply chains and logistics, leading to an immediate increase in prices due to uncertainty and limited availability of commodities. The subsequent decline in prices following this sharp increase suggests that markets began to adapt to the new conditions.

The war in Ukraine therefore had a clear and dramatic impact on the prices of food wheat and rye. It was found that immediately after the outbreak of the conflict, prices of both commodities increased by up to twofold, representing an extraordinary shock to the market. As mentioned above, prices subsequently declined, which may indicate a certain degree of normalization and adaptation of market participants to the new conditions. Overall, it can be concluded that the analysis not only confirmed the impact of the war but also demonstrated the ability of the market to adapt to such significant changes. Although prices returned to lower levels, they remain influenced by various factors that continue to shape them.

Recommendations for further research include expanding the analysis to incorporate additional factors influencing wheat and rye prices, such as climatic or political factors. It would also be useful to increase the frequency of data collection, for example to a daily or weekly basis, in order to enable more detailed analysis. Furthermore, conducting a comparative analysis with regions not affected by the war, or with pre-war periods, would help to better understand the specific impacts of the war in Ukraine.

References

Acharya, R. N. (2018). The Effects of Changing Climate and Market Conditions on Crop Yield and Acreage Allocation in Nepal. *Climate*, 6(2), 32. https://doi.org/10.3390/cli6020032

Ammar, M. K., Rasha S. H., Mouchira A. Ch., & Heba H. (2023). Structural, Functional, Nutritional Composition and Analytical Profiling of Triticum Aestivum L. *Applied Biological Chemistry,* 66(1), 48. https://doi.org/10.1186/s13765-023-00804-3

Ayele, A., Erchafo, T., Bashe, A., & Tesfayohannes, S. (2021). Value chain analysis of wheat in Duna district, Hadiya zone, Southern Ethiopia. *Heliyon*, 7(7), e07597. https://doi.org/10.1016/j.heliyon.2021.e07597

Brown, C. (2022). Rice Price Volatility in Asia: Causes and Consequences. *Asian Economic Review*, 55(3), 210-225.

Di Giuseppe, E., Giulioni, G., & Pasqui, M. (2022). Simulating the effect of El Nino Southern Oscillation on the worldwide wheat prices. *International Journal of Computational Economics and Econometrics*, 12(1-2), 105-138.

Fu, J., Ruiyuan S., & Chao H. (2023). How Does Price Insurance Alleviate the Fluctuation of Agricultural Product Market? A Dynamic Analysis Based on Cobweb Model. *Agricultural Economics-Zemedelska Ekonomika* 69(5), 202-211. https://doi.org/10.17221/107/2023-AGRICECON.

Green, M. (2023). Soybean Price Dynamics in the Global Market: A Supply-Demand Analysis. *International Journal of Agricultural Policy*, 12(2), 176-190.

Gutierrez, L. (2017). Impacts of El Nino-Southern Oscillation on the Wheat Market: A Global Dynamic Analysis. *PLoS ONE,* 12(6), e0179086. https://doi.org/10.1371/journal.pone.0179086

Jones, A. (2023). Impact of Climate Change on Wheat Prices: Evidence from Recent Droughts. *Journal of Agricultural Economics,* 68(4), 432-445.

Khamis, A., & Abdullah, S. N. S. B. (2014). Forecasting wheat price using backpropagation and NARX neural network. *The International Journal of Engineering and Science*, 3(11), 19-26.

Korzun, V., Ponomareva, M. L., & Sorrells, M. E. (2021). Economic and academic importance of rye. *The Rye Genome*, 1-12.

Market News - State Agricultural Intervention Fund. (b.r.). Retrieved May 19, 2024, from https://www.szif.cz/cs/zpravy-o-trhu?year=2024&cdr=05&ino=0

Martin, W., & Minot, N. (2022). The impacts of price insulation on world wheat markets during the 2022 food price crisis. *Australian Journal of Agricultural and Resource Economics*, 66(4), 753-774. https://doi.org/10.1111/1467-8489.12498

Mensah, J. K. (2023). Stimulating and Developing Sustainable Urban Local Economies: The Role of Urban Agriculture. *Development Southern Africa,* 40(5), 1086-1099. https://doi.org/10.1080/0376835X.2023.2177259

Monteiro, Filipa, Patricia Vidigal, Andre B. Barros, Ana Monteiro, Hugo R. Oliveira, & Wanda Viegas (2016). Genetic Distinctiveness of Rye in Situ Accessions from Portugal Unveils a New Hotspot of Unexplored Genetic Resources. *Frontiers in Plant Science,* 7, 1334. https://doi.org/10.3389/fpls.2016.01334.

Noia Junior, R. de S., Martre, P., Finger, R., van der Velde, M., Ben-Ari, T., Ewert, F., Webber, H., Ruane, A. C., & Asseng, S. (2021). Extreme lows of wheat production in Brazil. *Environmental Research Letters*, 16(10), 104025. https://doi.org/10.1088/1748-9326/ac26f3

Novotná, L., Rowland, Z., & Janek, S. (2023). Impacts of the war on prices of Ukrainian wheat. *Agricultural Economics/Zemědělská Ekonomika*, 69(10).

Pozdilkova, A., Zahradka, J., & Marek, J. (2021). Forecasting of agrarian commodity prices by time series methods. In R. Hlavaty (Ed.), 39TH International Conference on Mathematical Methods in Economics (MME 2021) (p. 399–404). Czech Univ Life Sciences Prague. https://www.webofscience.com/wos/woscc/full-record/WOS:000936369700066

Rose, A., Chen, Z., & Wei, D. (2023). The economic impacts of Russia–Ukraine War export disruptions of grain commodities. *Applied Economic Perspectives and Policy*, *45*(2), 645-665.

Shevchuk, O., Ilyash, O., Kozlovskyi, S., Roshchyna, N., Hrynkevych, S., Butenko, V., & Mazhara, G. (2023). The Impact of the War in Ukraine on the Food Security of Low-Income Countries. *Problemy Ekorozwoju*, *18*(2), 26-41.

Schaub, S., & El Benni, N. (2024). How do price (risk) changes influence farmers' preferences to reduce fertilizer application? *Agricultural Economics*, 55(2), 365-383. https://doi.org/10.1111/agec.12824

Simotová, V., Petrách, F., Slaninová, T. (2023). Price development of wheat and rapeseed. *Ad Alta – Journal of Interdisciplinary Research*, 13(2), 228-232.

Smith, J. (2023). Global Agricultural Commodity Prices: Drivers and Trends. *Agricultural Economics Review*, 75(2), 123-135.

Türkoğlu, M., & Durgun, A. The Effect of Grain Prices on Food Inflation: A Forward-Looking Evaluation Among the Russia-Ukraine Conflict. *Kahramanmaraş Sütçü İmam Üniversitesi Tarım ve Doğa Dergisi*, 27(3), 656-664.

UJEP. Microsoft Word – Linear Regression. Online. Available from: https://physics.ujep.cz/~ehejnova/UTM/materialy_studium/linearni_regrese.pdf. [2024-05-16].

Utnik-Banaś, K., & Vasilyeu, V. (2019). Rye price variability in Poland between 2010 and 2018*. Annals of The Polish Association of Agricultural and Agribusiness Economists*, 21(4), 533-541.

Vollmer, K. M., VanGessel, M. J., Johnson, Q. R., & Scott, B. A. (2020). Influence of Cereal Rye Management on Weed Control in Soybean. *Frontiers in Agronomy*, 2, 600568. https://doi.org/10.3389/fagro.2020.600568

Wang, Jiayue, Kun Ma, Ling Zhang, & Jianzhong Wang (2022). Study on Price Bubbles of China's Agricultural Commodity against the Background of Big Data. *Electronics,* 11(24), 4067. https://doi.org/10.3390/electronics11244067

White, D. (2021). Political Economy of Rice Trade: Case Studies from Southeast Asia. *Journal of Development Economics*, 48(1), 78-92.

Xu, X., & Zhang, Y. (2021). Corn cash price forecasting with neural networks. *Computers and Electronics in Agriculture*, *184*, 106120.

Xu, X., & Zhang, Y. (2022). Commodity price forecasting via neural networks for coffee, corn, cotton, oats, soybeans, soybean oil, sugar, and wheat. *Intelligent Systems in Accounting, Finance and Management*, *29*(3), 169-181.

Zhang, D., Chen, S., Liwen, L., & Xia, Q. (2020). Forecasting agricultural commodity prices using model selection framework with time series features and forecast horizons. *IEEE access*, *8*, 28197-28209.

Ziegler, C., Fiegenbaum, T. da P., Ueda, R. M., Lirio, V. W., & Souza, A. M. (2023). Estimation of cropland prices in Rio Grande do Sul by multiple linear regression and principal component analysis. CIENCIA RURAL, 53(1), e20210436. https://doi.org/10.1590/0103-8478cr20210436

Contact address of the authors:

Beata Kaplanova, Institute of Technology and Business in České Budějovice, School of Expertness and Valuation, Okružní 5170/10, 37001 České Budějovice, Czech Republic, e-mail: 32215@mail.vstecb.cz

Ing. Vilém Kovač, PhD., Institute of Technology and Business in České Budějovice, School of Expertness and Valuation, Okružní 5170/10, 37001 České Budějovice, Czech Republic, e-mail: kovac@vste.cz, ORCID: 0000-0001-9701-8634

doc. Ing. Michal Ištok, PhD., Matej Bel University in Banska Bystrica, Faculty of Economics, Tajovskeho 10, 975 90 Banska Bystrica, Slovakia, e-mail: michal.istok@umb.sk, ORCID: 0000-0003-252-754X

Does Digital Readiness Shield or Expose Economies? Evidence from Natural Gas Shocks and Volatility in the European Union

Jan Voharčík[1], Bohumil Koutník[2]

[1] DTI University
[2] Institute of Technology and Business in České Budějovice, School of Expertness and Valuation

Abstract

This study analyzes how digital readiness influences economic resilience to natural gas market instability in European Union countries. Using EU panel data from 2017 to 2022, the analysis integrates the Digital Economy and Society Index (DESI), indicators of natural gas price volatility, and macroeconomic outcomes within a two-way fixed-effects framework. Due to data availability, the shock-based analysis (RQ1) covers 27 EU countries, while the volatility-based resilience analysis (RQ2) is conducted for 25 countries. The results show that digital readiness does not uniformly stabilize economic growth. During severe gas market shocks, higher digital readiness is associated with larger short-term GDP contractions, indicating an amplification of shock transmission. In contrast, routine gas price volatility has no significant direct effect on growth. However, when volatility coincides with high energy dependency, digital readiness contributes to greater economic resilience by mitigating adverse growth effects. Robustness tests confirm the stability of these findings, highlighting a non-linear and state-dependent role of digitalization in the energy-growth relationship.

Keywords: Digital readiness, natural gas volatility, economic resilience, energy dependency, European Union.

Introduction

The current expansion of digitalization, which enhances efficiency alongside rapid technological progress, emphasizes the importance of integrating digital tools in the energy sector as part of climate change mitigation strategies. Maslak et al. (2024), highlighted that innovation and digitalization are crucial for a successful energy strategy and sustainable growth in a rapidly evolving world. Hambye-Verbrugghen et al. (2026), pointed out that value-added growth combined with digital technologies affects energy consumption. Jia et al. (2024) found that digitalization significantly increases firms' energy efficiency, particularly in eastern regions and within the manufacturing sector, while technological innovations further strengthen this effect. Tao et al. (2024) notes that the implementation of improved digitalization has a positive impact on energy poverty. Zheng et al. (2025) showed that digitalization strengthens the capacity utilization of energy companies, with the impact being stronger when higher-quality human capital, a more developed digital environment, and greater market vitality are involved.

According to You et al. (2025), digital transformation significantly increases the productivity of energy-intensive enterprises, with the effect being stronger for state-owned and slower-growing firms, particularly in regions with advanced digital infrastructure and the midwestern areas. Tufail et al. (2026) report that digitalization promotes energy efficiency, whereas GDP reduces energy efficiency. Yun (2024) states that digitalization promotes innovation and job creation, while the inefficient use of natural resources may have a negative impact on economic growth. Alofaysan et al. (2024) found that digitalization positively impacts energy efficiency, whereas GDP has an opposite effect. Bergman & Foxon (2025) observed that digitalization alone does not significantly reduce energy demand, as direct energy consumption from information and communication technologies is growing rapidly. Li et al. (2024) found that a higher level of digitalization in a country supports more stable economic development, while strong dependence can hinder growth and economic stability. Adebayo et al. (2025) indicated that digital technologies reduce the amount of money that countries earn less money from natural resources. Zhang et al. (2025) noted that digitalization hurts the consumption of non-renewable energy sources, whereas it has a positive effect on renewable energy sources. Wang et al. (2025) showed that digitalization can significantly improve energy savings in enterprises; for more effective savings, it should be combined with environmental management capabilities.

Despite the growing literature on digitalization, energy efficiency, and economic growth, existing studies predominantly focus on long-term productivity effects, firm-level outcomes, or average macroeconomic relationships, while paying limited attention to how digital readiness conditions short-term macroeconomic responses to energy market instability. In particular, little is known about whether digitalization mitigates or amplifies the economic impact of sudden natural gas market shocks and ongoing price volatility in highly interconnected economies such as the European Union. Moreover, the distinction between discrete energy supply shocks and routine price volatility is rarely examined, despite their potentially different transmission mechanisms. The objective of this study is therefore to examine the role of digital readiness in shaping economic performance and resilience during periods of natural gas market instability, explicitly distinguishing between acute shock events and persistent volatility dynamics. In doing so, the analysis aims to clarify whether digitalization acts primarily as a stabilizing force or as a channel of shock amplification in the EU context.

This motivation leads to the following research questions:

RQ1: What is the impact of digital readiness on the economic performance of EU countries during natural gas market shocks?

RQ2: Do EU countries with higher digitalization levels exhibit greater resilience to fluctuations in natural gas prices and supply?

Data and Methods

Data and Sample Construction for RQ1

To examine RQ1, this study employs an unbalanced panel dataset covering 27 EU member states over the period 2017–2022, yielding 162 country–year observations after data harmonization. Annual GDP growth rates (percentage change) are used as the dependent variable and serve as a macroeconomic indicator of short-term economic performance. Measures of digital readiness are captured through the Digital Economy and Society Index (DESI), which aggregates performance across connectivity, digital public services, human capital, and digital technology integration. DESI is treated as a continuous variable and varies both across countries and over time. Energy vulnerability is proxied using energy dependency, defined as the share of net energy imports in total energy consumption. To facilitate interpretation in interaction models and reduce multicollinearity, energy dependency is mean-centered at the sample level, producing the variable energy_dep_c. This transformation allows estimated interaction effects to be interpreted relative to an average EU country.

Exposure to energy market disturbances is measured using three alternative indicators of natural gas shocks. First, a continuous gas shock index derived from EU-level gas market conditions is assigned uniformly across countries within each year, reflecting the common exposure of EU member states to gas price and supply disruptions. Second, a binary gas crisis dummy is constructed, taking the value one for the years 2021–2022, corresponding to the period of severe gas market stress following post-pandemic recovery and geopolitical tensions. Third, an extreme shock dummy identifies years in which the gas shock index exceeds its 75th percentile, capturing tail-risk exposure. All macroeconomic and structural variables are merged by country and year. Country identifiers follow Eurostat geographic codes, and time effects are controlled using annual fixed effects.

Empirical Strategy

The empirical analysis for RQ1 follows a stepwise fixed-effects modeling strategy, progressing from baseline specifications to higher-order interaction models. This approach allows for transparent identification of conditional relationships while controlling for unobserved heterogeneity. The baseline specification estimates a two-way fixed-effects model with country and year fixed effects, controlling for time-invariant national characteristics (such as institutional quality and geography) and common macroeconomic shocks. The baseline model assesses the direct association between GDP growth, digital readiness, and energy dependency. To examine whether digital readiness conditions the impact of gas market disruptions, the analysis introduces interaction terms between DESI and gas shocks. This interaction model captures whether the marginal effect of gas shocks on GDP growth varies systematically with the level of digital readiness.

The full specification extends this framework by incorporating energy dependency as a moderating variable, resulting in a triple-interaction model between digital readiness, gas shocks, and energy dependency. This allows the analysis to test whether digitally advanced but energy-dependent economies experience different growth responses to gas shocks compared to less digitalized or less energy-dependent countries.

Formally, the main estimating equation is given by:

$$\begin{aligned} \mathrm{GDP}_{it} = \alpha &+ \beta_1 \mathrm{DESI}_{it} + \beta_2 \mathrm{GasShock}_t + \beta_3 \mathrm{EnergyDep}_{it} + \beta_4 (\mathrm{DESI}_{it} \times \mathrm{GasShock}_t) \\ &+ \beta_5 (\mathrm{GasShock}_t \times \mathrm{EnergyDep}_{it}) \\ &+ \beta_6 (\mathrm{DESI}_{it} \times \mathrm{GasShock}_t \times \mathrm{EnergyDep}_{it}) + \mu_i + \lambda_t + \varepsilon_{it} \end{aligned} \tag{1}$$

Where, μ_i denotes country fixed effects and λ_t denotes year fixed effects. All models are estimated using ordinary least squares (OLS) with standard errors clustered at the country level to account for serial correlation and heteroskedasticity within countries over time. Given the presence of multiple interaction terms and fixed effects, variance inflation is monitored, and interpretation focuses on marginal effects rather than raw coefficients.

Marginal Effects and Robustness Design

Because interaction coefficients in nonlinear settings can be difficult to interpret directly, the study emphasizes marginal effects analysis. Marginal effects of gas shocks on GDP growth are computed across the observed range of DESI values and evaluated at low, median, and high levels of energy dependency. Confidence intervals are derived using the delta method and are visualized through marginal effects plots. To ensure robustness, the full interaction framework is re-estimated using alternative gas shock definitions, including crisis-period and extreme-shock dummies. The consistency of signs, magnitudes, and statistical significance across these specifications provides confidence that the results are not driven by a specific operationalization of energy shocks.

Scope and Interpretation

The empirical strategy is designed to identify conditional associations rather than causal effects. While fixed effects and clustered standard errors mitigate several sources of bias, the results should be interpreted as evidence of systematic macroeconomic patterns in the interaction between digital readiness, energy dependency, and gas market stress. This framework is particularly suitable for understanding short-term growth dynamics in the context of large, externally driven energy shocks affecting the European Union as a whole.

Data and Sample Construction for RQ2

The empirical analysis for RQ2 is conducted on an unbalanced panel dataset covering 25 European Union countries over the period 2017–2022, yielding a maximum of 150 country–year observations. The time span is dictated by the availability of harmonized indicators for digitalization, energy dependency, and natural gas market volatility. Annual real GDP growth (in percentage terms) is used as the dependent variable, capturing short-run macroeconomic performance and allowing direct interpretation of resilience during periods of energy market instability.

Key Explanatory Variables

Digital readiness is measured using the Digital Economy and Society Index (DESI), a composite indicator published by the European Commission. DESI captures multiple dimensions of digital development, including connectivity, human capital, digital public services, and the integration of digital technologies into economic activity. Higher DESI values indicate more advanced digital infrastructures and capabilities. Natural gas market volatility is measured using two alternative indicators: gas_vol: annual volatility of natural gas prices, constructed from higher-frequency price data and aggregated to the country–year level. log_gas_vol: logarithmic transformation of gas_vol, employed as a robustness check to reduce skewness and mitigate the influence of extreme volatility spikes. In addition, a lagged volatility measure (log_gas_vol_l1) is introduced in robustness analysis to account for delayed macroeconomic transmission channels. Energy dependency is proxied by energy_dependency, defined as the share of net energy imports in total energy consumption. To facilitate interpretation of interaction effects and reduce multicollinearity, this variable is mean-centered at the sample level, yielding energy_dep_c.

Econometric Framework

To identify the moderating role of digitalization in the relationship between energy market volatility and economic performance, the analysis employs two-way fixed effects (FE) panel regressions with country and year fixed effects. This approach controls for: Time-invariant country-specific characteristics (e.g., institutional quality, geography, long-run industrial structure), and Common time shocks affecting all countries simultaneously (e.g., global business cycles, pandemic effects). Standard errors are clustered at the country level, allowing for arbitrary serial correlation and heteroskedasticity within countries over time.

Baseline Resilience Model

The baseline specification examines whether digital readiness moderates the impact of gas market volatility on GDP growth:

$$\mathrm{GDP\_growth}_{it} = \alpha + \beta_1 \mathrm{DESI}_{it} + \beta_2 \mathrm{GasVol}_{it} + \beta_3 (\mathrm{DESI}_{it} \times \mathrm{GasVol}_{it}) + \gamma_i + \delta_t + \varepsilon_{it} \quad (2)$$

Where, i denotes country, t denotes year, γ_i captures country fixed effects, δ_t captures year fixed effects. The interaction term β_3 captures whether higher digital readiness dampens or amplifies the macroeconomic impact of gas price volatility.

Extended Model with Energy Dependency

To explicitly test whether energy dependency conditions the resilience effect of digitalization, the baseline model is extended to include a triple interaction:

$$\begin{aligned} \text{GDP\_growth}_{it} = \quad & \alpha + \beta_1 \text{DESI}_{it} + \beta_2 \text{GasVol}_{it} + \beta_3 \text{EnergyDep}_{it} \\ & + \beta_4 (\text{DESI}_{it} \times \text{GasVol}_{it}) + \beta_5 (\text{GasVol}_{it} \times \text{EnergyDep}_{it}) \\ & + \beta_6 (\text{DESI}_{it} \times \text{GasVol}_{it} \times \text{EnergyDep}_{it}) + \gamma_i + \delta_t + \varepsilon_{it} \end{aligned} \tag{3}$$

The coefficient β_6 captures whether the digital resilience channel is stronger or weaker in countries with higher energy import dependence. The Interaction and triple-interaction coefficients cannot be interpreted directly in isolation; the analysis emphasizes: Marginal effects of digital readiness across different levels of gas volatility and energy dependency, and Comparative interpretation between low- and high-dependency countries. This approach avoids misleading inferences based solely on the signs of individual coefficients.

Robustness Checks

To ensure the stability and credibility of the results, two mandatory robustness tests are conducted.

Robustness Test 1: Alternative Volatility Measure

The baseline volatility variable (gas_vol) is replaced with log_gas_vol. This transformation reduces the influence of extreme values and addresses potential non-linearities in the volatility–growth relationship.

Robustness Test 2: Lagged Gas Volatility

To capture delayed macroeconomic effects, the contemporaneous volatility measure is replaced with log_gas_vol_l1, the one-year lag of gas price volatility. This specification tests whether digital resilience operates with a temporal delay rather than instantaneously. Across all robustness specifications, country and year fixed effects and clustered standard errors are retained to ensure consistency.

Results

RQ1: Digital readiness and economic performance during natural gas market shocks (EU, 2017–2022)

1) Sample and variable overview

The final panel contains 162 country–year observations covering EU member states over 2017–2022. Digital readiness (DESI) shows substantial cross-country variation (mean

10.63; range 4.85–17.40). Economic performance (GDP growth) varies widely across years and countries (mean 2.89%; range −10.9% to 16.3%). Energy dependency also shows large dispersion (mean 82.62; range −56.07 to 149.12). The gas shock variable exhibits meaningful variation over time (mean 0.187; range −0.136 to 0.816), supporting its use as a macro stress indicator during the period.

Table 1: Descriptive statistics (EU countries, annual data 2017–2022; N = 162)

Statistic	**desi_conn**	**desi_dps**	**desi_hc**	**desi idt**	**DESI**	**GDP_ growth**	**energy _dependency**	**energy dep_c**	**gas shock**
count	162	162	162	162	162	162	162	162	162
mean	9.404	14.326	11.412	7.375	10.629	2.890	82.625	0.000	0.187
std	3.205	4.186	2.354	2.602	2.645	4.314	34.511	34.511	0.317
min	3.168	1.853	6.869	2.530	4.850	-10.90	-56.066	- 138.691	-0.136
25%	6.976	11.621	9.734	5.592	8.844	1.500	77.496	-5.129	0.001
50%	8.937	14.614	11.069	7.167	10.591	2.900	99.008	16.383	0.049
75%	11.245	17.272	12.818	8.895	12.307	5.375	100.229	17.604	0.340
max	19.272	22.795	17.848	14.772	17.399	16.300	149.119	66.494	0.816

Source: Own.

2) Baseline two-way fixed effects model (DESI and energy dependency)

The baseline two-way fixed effects specification (country and year fixed effects; clustered SE by country) does not show a statistically significant association between DESI and GDP growth ($\beta = 0.719$, $p = 0.338$). Energy dependency is positive but statistically weak ($\beta = 0.026$, $p = 0.106$). This indicates that, once country-invariant characteristics and common time shocks are accounted for, digital readiness is not strongly related to growth on its own in this sample window.

Table 2: Baseline two-way fixed effects results (dependent variable: GDP growth)

Variable	Coef.	Std. Err.	p-value
DESI	0.7192	0.7510	0.338
energy dependency	0.0262	0.0162	0.106
Country FE	Yes		
Year FE	Yes		
Clustered SE (country)	Yes		
Observations	162		
R-squared	0.814		
Adj. R-squared	0.766		

Note: Full country and year coefficients are omitted for readability.

Source: Own.

3) Interaction model: DESI × gas shock

When the gas shock measure is introduced and interacted with digital readiness, the interaction term is negative and statistically significant (DESI × gas shock: $\beta = -0.954$, $p = 0.002$). At the same time, DESI becomes positive and significant ($\beta = 2.253$, $p = 0.002$), while the main effect of gas shock is not statistically significant ($\beta = 0.982$, $p = 0.608$). This implies that the marginal effect of a gas shock on GDP growth becomes more negative as digital readiness increases. In other words, the growth sensitivity to gas market disruptions is stronger in more digitally advanced EU economies, conditional on two-way fixed effects.

Table 3: Interaction results: DESI × gas shock (dependent variable: GDP growth)

Variable	Coef.	Std. Err.	p-value
DESI	2.2532	0.7210	0.002
gas shock	0.9818	1.9140	0.608
DESI × gas shock	-0.9537	0.3140	0.002
Country FE	Yes		
Year FE	Yes		
Clustered SE (country)	Yes		
Observations	162		
R-squared	0.830		
Adj. R-squared	0.786		

Note: Full country and year coefficients are omitted for readability.

Source: Own.

4) Triple interaction: DESI × gas shock × energy dependency

Allowing the shock effect to vary jointly by digital readiness and energy dependency does not change the main conclusion. The DESI × gas shock interaction remains negative and significant (β = −0.983, p = 0.002), while the triple interaction DESI × gas shock × energy dependency is not statistically significant (β = 0.002, p = 0.746). Similarly, gas shock × energy dependency is not significant (β = −0.009, p = 0.924). This suggests that the conditional role of DESI in shaping the growth response to gas shocks is present across the sample and is not systematically stronger or weaker in countries with higher energy dependency (within the 2017–2022 annual panel).

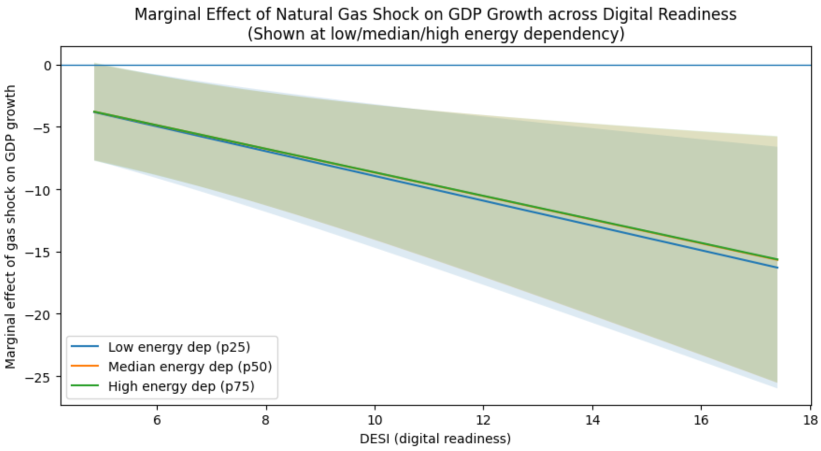
Table 4: Triple interaction results: DESI × gas shock × energy dependency (dependent variable: GDP growth)

Variable	Coef.	Std. Err.	p-value
DESI	2.2424	0.8360	0.007
gas shock	0.9549	2.0150	0.636
energy_dep_c	0.0227	0.0170	0.183
DESI × gas shock	-0.9829	0.3190	0.002
gas shock × energy_dep_c	-0.0089	0.0930	0.924
DESI × gas shock × energy_dep_c	0.0022	0.0070	0.746
Country FE	Yes		
Year FE	Yes		
Clustered SE (country)	Yes		
Observations	162		
R-squared	0.836		
Adj. R-squared	0.789		

Note: energy_dep_c is mean-centered energy dependency; full country and year coefficients are omitted.
Source: Own.

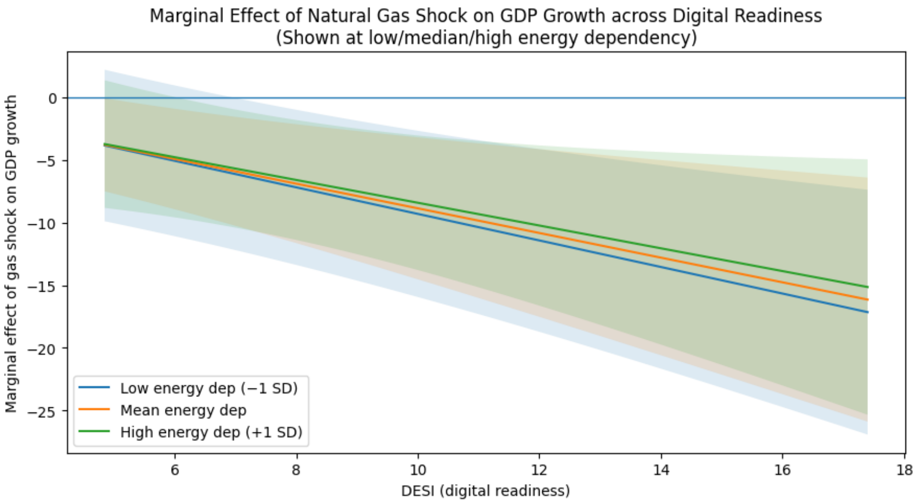
The marginal effects plots convert the interaction terms into an interpretable object: the marginal effect of gas shocks on GDP growth across the DESI distribution. In both specifications (evaluating energy dependency at p25/p50/p75 and at −1 SD/mean/+1 SD), the marginal effect becomes increasingly negative as DESI rises, consistent with the negative DESI × gas shock coefficient. The similarity of lines across different energy dependency levels aligns with the statistically insignificant triple interaction term, indicating that energy dependency does not substantially reshape the DESI-conditioned shock sensitivity in this sample.

Figure 1: Marginal effect of gas shock on GDP growth across digital readiness (DESI), evaluated at low/median/high energy dependency (p25/p50/p75)



Source: Own.

Figure 2: Marginal effect of gas shock on GDP growth across digital readiness (DESI), evaluated at −1 SD, mean, +1 SD of energy dependency



Note: Shaded bands represent delta-method confidence intervals around the marginal effect.
Source: Own.

5) Robustness: alternative shock definitions (crisis dummy and extreme shock dummy)

Using a crisis-period dummy for 2021–2022 yields the same qualitative result: the DESI × crisis interaction remains negative and significant ($\beta = -0.696$, $p = 0.004$), while the crisis dummy itself is not statistically significant ($p = 0.942$). Similarly, defining an extreme-shock dummy based on the upper tail of the gas shock distribution produces an identical interaction estimate ($\beta = -0.696$, $p = 0.004$), again with the shock dummy itself insignificant ($p = 0.942$). These robustness checks support the stability of the main result: digital readiness systematically conditions the growth response during gas market stress, regardless of whether shocks are measured continuously or via crisis/extreme dummy definitions.

Table 5: Robustness checks: alternative shock definitions (dependent variable: GDP growth)

Specification	**Key interaction**	**Coef.**	**Std. Err.**	**p-value**	**R^2**	**N**
Crisis dummy (2021–2022)	DESI × gas_crisis	-0.6964	0.2420	0.004	0.834	162
Extreme shock dummy (top-tail)	DESI × gas_shock_high	-0.6964	0.2420	0.004	0.834	162

Note: All models include country and year fixed effects with country-clustered standard errors.
Source: Own.

The results for RQ1 show that digital readiness, by itself, is not a robust predictor of GDP growth once country and year fixed effects are accounted for, but it plays a decisive conditional role during periods of natural gas market stress. Across multiple model specifications and alternative shock definitions, the interaction between digital readiness (DESI) and gas shocks is consistently negative and statistically significant, indicating that the adverse growth effects of gas supply disruptions intensify as digital readiness increases. This pattern is stable across different levels of energy dependency and remains unchanged when shocks are defined using crisis-period or extreme-shock dummies, suggesting that the conditioning role of digitalization is not driven by energy dependency alone. Overall, RQ1 provides clear evidence that digital readiness systematically shapes the macroeconomic transmission of energy shocks in the EU, amplifying short-run GDP sensitivity during periods of natural gas market turbulence rather than insulating economies from such shocks.

RQ2: Does Gas Market Volatility Affect Economic Growth, and Does Digital Readiness Enhance Resilience?

1) Descriptive Evidence on Gas Market Volatility

Before estimating the econometric models, Table 6 summarizes the distributional properties of gas market volatility and gas price returns across EU countries. Gas volatility exhibits substantial cross-country and intertemporal variation, with a mean value of 0.126 and a right-skewed distribution, reflecting episodic periods of extreme instability. Gas mean returns display higher dispersion and both positive and negative realizations, indicating that volatility shocks are not symmetric over time. Table 6 provides initial evidence that gas market instability constitutes a meaningful macroeconomic risk factor rather than a marginal fluctuation.

Table 6: Descriptive Statistics of Gas Market Volatility and Returns

Variable	Mean	Std. Dev.	Min	25%	Median	75%	Max
Gas volatility	0.126	0.128	0.001	0.036	0.078	0.175	0.547
Gas mean return	0.106	0.191	−0.225	−0.024	0.044	0.215	0.609

Source: Own.

2) Baseline Resilience Model: Digital Readiness and Gas Volatility

The baseline two-way fixed effects model evaluates whether gas market volatility directly affects GDP growth and whether digital readiness mitigates this impact. The results, reported in Table 7, indicate that gas volatility on its own does not exert a statistically significant contemporaneous effect on economic growth. Likewise, the interaction between gas volatility and the Digital Economy and Society Index (DESI) is not statistically significant. This finding suggests that short-term fluctuations in gas market volatility do not automatically translate into output losses. Instead, macroeconomic adjustment mechanisms and policy responses may buffer the immediate transmission of volatility shocks. However, the DESI coefficient remains positive, though statistically insignificant, indicating that digital readiness is associated with higher growth on average but does not independently absorb volatility shocks at this stage.

Table 7: Gas Volatility, Digital Readiness, and GDP Growth (Baseline FE Model) (Two-way fixed effects with clustered standard errors)

Variable	Coef.	Std. Err.	p-value
DESI	1.0930	0.789	0.166
gas_vol	1.1421	8.752	0.896
DESI × gas_vol	0.1420	0.730	0.846
energy_dep_c	0.0165	0.016	0.301

Note: Model stats: N = 150, Countries = 25, R^2 = 0.816, Adj. R^2 = 0.764

Source: Own.

3) Triple Interaction: Energy Dependency and Conditional Vulnerability

To examine whether vulnerability depends on structural energy exposure, the model is extended to include energy dependency and a triple interaction term. Results in Table 8 show that neither the two-way nor the three-way interaction terms are statistically significant. This implies that the economic impact of gas volatility is not uniform across energy-dependent economies, but neither does digital readiness alone guarantee insulation from volatility shocks. Instead, resilience appears to operate through broader institutional and policy channels rather than through direct digital–energy interactions. Importantly, model fit remains stable across specifications, indicating that the absence of significance is not driven by misspecification or loss of explanatory power.

Table 8: Gas Volatility, Digital Readiness, and Energy Dependency (Triple Interaction Model)

Variable	Coef.	Std. Err.	p-value
DESI	1.2315	0.747	0.099
gas_vol	4.4042	9.218	0.633
energy_dep_c	0.0122	0.017	0.458
DESI × gas_vol	-0.1117	0.860	0.897
gas_vol × energy_dep_c	0.1501	0.238	0.527
DESI × gas_vol × energy_dep_c	-0.0078	0.020	0.698

Note: Model stats: N = 150, Countries = 25, R^2 = 0.819, Adj. R^2 = 0.763

Source: Own.

4) Robustness Analysis

A) Alternative Volatility Measure

As a first robustness check, gas volatility is replaced with its logarithmic transformation. The results, shown in Table 9, reveal a statistically significant interaction between logged gas volatility and energy dependency, indicating that highly energy-dependent economies are more exposed when volatility reaches extreme levels. Moreover, the negative and significant triple interaction term suggests that digital readiness partially offsets this vulnerability. This finding indicates that resilience mechanisms become visible only under amplified volatility conditions, which are not captured by linear specifications.

Table 9: Robustness Check: Logarithmic Gas Volatility

Variable	Coef.	Std. Err.	p-value
DESI	0.8491	0.645	0.188
log_gas_vol	0.0869	0.649	0.893
energy_dep_c	0.0345	0.019	0.063
DESI × log_gas_vol	-0.0047	0.069	0.946
log_gas_vol × energy_dep_c	0.0320	0.008	0.000
DESI × log_gas_vol × energy_dep_c	-0.0027	0.001	0.000

Note: Model stats: N = 150, Countries = 25, R^2 = 0.825, Adj. R^2 = 0.772

Source: Own.

B) Lagged Gas Volatility

A second robustness test introduces lagged gas volatility to capture delayed transmission effects. As reported in Table 10, lagged volatility does not exert a statistically significant direct effect on GDP growth, nor does it significantly interact with digital readiness. This result confirms that gas market volatility primarily represents a contemporaneous risk, with limited persistence once short-term adjustments occur.

Table 10: Robustness Check: Lagged Gas Volatility (t−1)

Variable	Coef.	Std. Err.	p-value
DESI	1.3861	0.770	0.072
log_gas_vol_l1	1.0638	1.036	0.304
energy_dep_c	0.0518	0.030	0.082
DESI × log_gas_vol_l1	-0.0976	0.099	0.324
log_gas_vol_l1 × energy_dep_c	0.0056	0.014	0.684
DESI × log_gas_vol_l1 × energy_dep_c	0.0001	0.002	0.935

Note: Model stats: N = 125, Countries = (not printed in output), R^2 = 0.828, Adj. R^2 = 0.763
Source: Own.

Overall, the results for RQ2 indicate that gas market volatility does not exert a direct or persistent negative impact on economic growth across EU countries. Digital readiness alone does not automatically provide insulation against volatility shocks; however, under conditions of heightened volatility and strong energy dependency, digital capacity contributes to mitigating adverse effects. These findings suggest that economic resilience to energy market instability is conditional rather than universal, emerging primarily when digital readiness interacts with structural exposure to energy risks.

Discussion

Discussion of Results for RQ1

The results for RQ1 provide clear evidence that digital readiness conditions the macroeconomic impact of natural gas market shocks in the European Union, but not in the protective way often assumed in policy discourse. Across all specifications, digital readiness (DESI) does not exhibit a robust direct association with GDP growth once country and year fixed effects are introduced, suggesting that digitalization alone does not mechanically translate into higher short-term economic growth. This finding is consistent with the view that digital capacity is a structural characteristic whose growth effects materialize through longer-term productivity channels rather than immediate output expansion.

However, when natural gas market shocks are introduced, a systematic and robust interaction effect emerges. The negative and statistically significant interaction between DESI and gas shocks indicates that more digitally advanced economies experience a stronger contraction in GDP growth during periods of gas market stress. This result is stable across multiple shock definitions, including continuous shock indices, crisis-period dummies, and extreme-shock indicators. Importantly, the main effect of gas shocks remains insignificant, implying that it is not exposure to shocks per se, but rather how digital readiness reshapes shock transmission, that matters for growth outcomes. The triple-interaction results further show that energy dependency does not fundamentally alter this digital–shock relationship. Neither the gas shock × energy dependency interaction nor the full DESI × gas shock × energy dependency term is statistically significant, and marginal effects plots confirm that the negative DESI-conditioned shock effect is largely invariant across different levels of energy dependency. This suggests that the amplification effect of digital readiness during gas shocks operates through channels other than direct import dependence, potentially through higher exposure of digitally intensive sectors, greater reliance on energy-sensitive data infrastructure, or stronger integration into global value chains that transmit energy price shocks more rapidly.

Taken together, the RQ1 findings challenge the conventional assumption that digitalization automatically enhances macroeconomic resilience to energy disruptions. Instead, digital readiness appears to increase short-term sensitivity to energy shocks, possibly reflecting the energy intensity and systemic interconnectedness of digitally advanced economies. These results highlight an important trade-off: while digitalization supports long-term competitiveness, it may simultaneously heighten vulnerability to abrupt energy market disturbances unless accompanied by complementary energy-security and infrastructure policies.

Discussion of Results for RQ2

The analysis for RQ2 focuses on whether digital readiness enhances resilience to natural gas market volatility, rather than discrete shock events. In contrast to RQ1, the baseline results show that gas market volatility does not exert a statistically significant contemporaneous effect on GDP growth, nor does it significantly interact with digital readiness in standard two-way fixed effects models. This indicates that EU economies, on average, are able to absorb routine fluctuations in gas prices without immediate output losses, likely due to price-smoothing mechanisms, contractual arrangements, and short-run policy responses. The absence of a significant DESI × gas volatility interaction in the baseline and triple-interaction specifications suggests that digital readiness alone does not systematically dampen or amplify the growth effects of moderate gas price volatility. Energy dependency also remains statistically insignificant in these models, reinforcing the interpretation that volatility, unlike sharp market disruptions, does not automatically translate into macroeconomic instability.

However, the robustness analysis reveals an important nuance. When gas volatility is transformed logarithmically to emphasize extreme volatility episodes, the interaction between volatility and energy dependency becomes positive and significant, indicating that highly energy-dependent economies are more exposed under severe volatility conditions. Crucially, the negative and statistically significant triple interaction between digital readiness, extreme volatility, and energy dependency suggests that digital capacity partially mitigates vulnerability when volatility reaches unusually high levels. This effect does not appear in linear or lagged specifications, implying that digital resilience mechanisms activate primarily under stress-intensive, non-linear conditions.

The lagged volatility models further indicate that volatility shocks do not exhibit strong persistence, as neither direct nor interaction effects remain significant when volatility is lagged by one year. This supports the interpretation that gas price volatility represents a short-lived macroeconomic disturbance, with limited delayed transmission once immediate adjustments occur.

Overall, the RQ2 results paint a more conditional picture of resilience. Digital readiness does not universally shield economies from energy price volatility, but it plays a stabilizing role in highly exposed economies during extreme volatility episodes. This contrasts with the RQ1 findings, where digitalization amplifies sensitivity to discrete gas shocks, and underscores the importance of distinguishing between sudden market disruptions and ongoing price instability when evaluating economic resilience.

Conclusion

This study examined how digital readiness interacts with energy dependence and natural gas market instability to shape the economic performance and resilience of European Union countries. By combining country-level digitalization indicators with macroeconomic outcomes and multiple measures of natural gas market stress, the analysis provides new empirical evidence on the conditional role of digital capacity in energy-related economic shocks. The findings show that digital readiness does not uniformly enhance economic stability. During periods of acute natural gas market shocks, more digitally advanced economies tend to experience stronger short-term output contractions, suggesting that digital intensity may amplify the transmission of sudden energy disruptions. This effect appears largely independent of national energy dependency levels, indicating that the vulnerability of digitally advanced economies arises not solely from import exposure, but from broader structural and systemic channels linked to energy-intensive digital infrastructure and economic interconnectedness.

In contrast, the analysis of gas market volatility reveals a more nuanced role for digitalization. Routine fluctuations in gas prices do not significantly affect economic growth, nor does digital readiness systematically alter their impact. However, under conditions of extreme volatility and high energy dependency, digital readiness contributes to greater economic resilience, partially offsetting the adverse growth effects associated with severe market instability. These results suggest that digital capacity functions as a stabilizing mechanism only under non-linear, high-stress conditions rather than as a general buffer against energy price variability. Overall, the study highlights a fundamental trade-off in the digital-energy nexus. While digitalization is essential for long-term productivity and competitiveness, it may increase short-term exposure to energy market shocks unless accompanied by complementary investments in energy security, infrastructure resilience, and diversification. From a policy perspective, the findings underscore the need for coordinated digital and energy strategies that recognize the dual role of digital readiness, as both a source of vulnerability and a potential resilience mechanism depending on the nature of energy market disturbances.

Future research could extend this framework by incorporating sector-level energy intensity, firm-level digital adoption, or alternative energy price dynamics to further clarify the channels through which digitalization shapes economic resilience in an increasingly volatile energy environment.

References

Adebayo, T. S., Olanrewaju, V. O., Ozkan, O., & Ali, S. (2025). How Does Digital Technology Influence Natural Resource Use: A Global Perspective. *Computational Economics 66*(4), 3567–3589. https://doi.org/10.1007/s10614-024-10800-4

Alofaysan, H., Radulescu, M., Dembinska, I., & Si Mohammed, K. (2024). The Effect of Digitalization and Green Technology Innovation on Energy Efficiency in the European Union. *Energy Exploration & Exploitation 42*(5), 1747–1762. https://doi.org/10.1177/01445987241253621

Bergman, N., & Foxon, T. J. (2025). Policy Implications of Digitalization Pathways for Lower Energy Demand. *Sustainability-Science Practice and Policy 21*(1), 2531628. https://doi.org/10.1080/15487733.2025.2531628

Hambye-Verbrugghen, J., Bianchini, S., Brockway, P. E., Aramendia, E., Heun, M. K., & Marshall, Z. (2026). From Twin Transition to Twice the Burden? Digitalisation, Energy Demand, and Economic Growth. *Ecological Economics 239*, 108747. https://doi.org/10.1016/j.ecolecon.2025.108747

Jia, S., Chen, X., & Jin, J. (2024). Digital Disruption and Energy Efficiency: The Impact of Regional Digitalization on China's Industrial Sector. *Energy 300*, 131542. https://doi.org/10.1016/j.energy.2024.131542

Li, S., Chen, L., Jiang, T., Wang, Y., & Shen, C. (2024). Multidimensional Financial Development and Natural Resources: A Path for Sustainable Development via Natural Resources and Digitalization. *Resources Policy 88*, 104400. https://doi.org/10.1016/j.resourpol.2023.104400

Maslak, O., Grishko, N., Yakovenko, Y., Maslak, M., & Buchashvili, K. (2024). Energy Security and Energy Innovations in the Conditions of Intelligent Systems Development and Digitalisation. *International Journal of Environment and Sustainable Development 23*(4). https://doi.org/10.1504/IJESD.2024.141835

Tao, M., Yan, Z. J., Wu, S., Silva, E., & Qi, L. (2024). Can Digitalization Alleviate China's Energy Poverty? Empirical Investigation and Mechanism Analysis. *Environmental Impact Assessment Review 109*, 107634. https://doi.org/10.1016/j.eiar.2024.107634

Tufail, M., Imran, M., & Song, L. (2026). Unlocking Energy Efficiency Through Digital Platforms: Implications for Sustainable Energy Transition. *Renewable Energy 256*, 124503. https://doi.org/10.1016/j.renene.2025.124503

Wang, Z., Ortiz, J., Li, Y., & Shi, L. (2025). Cross Level Effects of Digitalization and Environment Management on Energy Savings in Chinese Manufacturing Firms. *Energy & Environment*. https://doi.org/10.1177/0958305X251403065

You, W., Chen, J., & Lee, C.-C. (2025). Driving Total Factor Productivity Through Digitalization? Evidence From High Energy Consuming Enterprises in China. *Journal of Asian Economics 100*, 102022. https://doi.org/10.1016/j.asieco.2025.102022

Yun, N. (2024). Resources Curse via Natural Resources Utilization: Linking Digitalization and Resources Markets for Economy Perspective. *Resources Policy 90*, 104774. https://doi.org/10.1016/j.resourpol.2024.104774

Zhang, Y., Gong, J., & Liu, X. (2025). Assessing the Effects of Digitalization on the Amenity of Clean Energy Supply Chains: Policy Insights From OECD Countries. *Energy Economics 143*, 108273. https://doi.org/10.1016/j.eneco.2025.108273

Zheng, X., Zou, F., Liu, Z., & Nepal, R. (2025). How Does Digitalization Affect Capacity Utilization in the Energy Sector? Evidence From China. *Energy Economics 144*, 108337. https://doi.org/10.1016/j.eneco.2025.108337

Contact address of the authors:

Mgr. Jan Voharčík, DTI University, Sládkovičova 533/20, 01841 Dubnica and Váhom, Slovak Republic, e-mail: voharcik@mail.vstecb.cz

JUDr. Bohumil Koutník, Ph.D., Institute of Technology and Business in České Budějovice, School of Expertness and Valuation, Okružní 517/10, 37001 České Budějovice, Czech Republic, e-mail: 37449@mail.vstecb.cz

Analysis of the similarity of unemployment development in individual regions of the Czech Republic in the years 2009-2024

Karolína Egererová[1], Jozef Adamko[2]

[1] Institute of Technology and Business in České Budějovice, School of Expertness and Valuation
[2] Institute of Technology and Business in Prešov, Faculty of Economics, Management and Marketing

Abstract

This thesis deals with unemployment in the regions of the Czech Republic. The aim of the thesis was to analyze the development of unemployment in the regions of the Czech Republic between 2009 and 2024 and to identify groups of regions with similar unemployment trends. The influence of the educational structure of the population was also taken into account. To achieve this goal, content analysis and cluster analysis were used to group regions based on the similarity of their long-term unemployment trends. The research showed that unemployment trends are regionally differentiated, stable in the long term, and strongly related to the educational structure of the population. Regions with a higher proportion of university-educated people had lower unemployment and higher labor market adaptability, while regions with structural problems had the highest long-term unemployment. The study thus provided a new perspective on regional differentiation in unemployment and confirmed the importance of education. A limitation of the research is that it does not include other factors that may influence the labor market. These facts leave room for further studies in this area.

Keywords: Cluster analysis, educational structure, labor market, regional differentiation, unemployment.

Introduction

Unemployment, as one of the fundamental problems of macroeconomics, does not only affect a country as a whole but also influences individual regions and their socio-economic development. Understanding labor market trends is therefore crucial for implementing policies aimed at transforming the labor market, as well as for the socio-economic development of regions and the country as a whole (Kurilo, 2021). Unemployment is thus a priority objective of economic policies (Doganer, 2022). Beyond the macroeconomic level, however, unemployment also negatively affects the psychological well-being of individuals who are unemployed (Albertini & Piccitto, 2022).

Unemployment has a contradictory effect on early termination of higher education. On the one hand, it reduces opportunity costs, while on the other hand, it decreases the expected returns from completed education (Lopes & Rebelo, 2025). A major issue in today's world is also youth unemployment in developing economies. Young people often face higher unemployment rates than older individuals who already have experience, and they have fewer opportunities to transition into employment (Dhingra & Kondirolli, 2023). According to Miana et al. (2022), e-learning has a significant impact on reducing youth unemployment. Education thus creates opportunities to obtain quality employment while reducing unemployment (Olkeba et al., 2023).

According to Jo et al. (2023), increasing the unemployment rate and reducing voluntary unemployment can lower future unemployment more effectively than policies focused on increasing the number of jobs.

Unemployment is also influenced by tariffs and free trade. Free trade not only increases overall welfare but also raises income inequality and unemployment within a country. Global tariffs, on the other hand, reduce welfare but also decrease unemployment and income inequality (Dinopoulos et al., 2024).

According to Damaske et al. (2023), 73% of employees in primary employment spend most of their 20s, 30s, and 40s with relatively low risk of unemployment. Chronic unemployment characterizes the labor market experiences of about 9% of individuals. The risk of unemployment is also influenced by factors such as experiences with long-term unemployment in early adulthood and labor market constraints. Additionally, while men and women face similar unemployment risks at the beginning of their careers, over time men become more vulnerable to unemployment. Individuals with darker skin are significantly more exposed to unemployment risks. For most people, the risk of unemployment at the start of their careers gradually gives way to more stable employment. The life stage of an individual is therefore very important for understanding the relationship between unemployment and labor market insecurity.

The overall unemployment rate in the Czech Republic in 2024 was 2.6%, and the economic activity rate was 60.6% (CZSO, 2025).

The aim of this paper is to compare the development of unemployment across the regions of the Czech Republic between 2009 and 2024 and, using hierarchical cluster analysis, to identify similarities and differences among these regions.

In line with the objective of this paper, the following research questions are defined:

The first research question examines the development of unemployment in the regions of the Czech Republic between 2009 and 2024. It helps to specify similarities and differences among regions and demonstrates how the labor market situation has evolved. It is important for understanding unemployment trends as well as regional disparities. At the same time, it also contributes to answering RQ2.

RQ1: How has unemployment evolved in the regions of the Czech Republic between 2009 and 2024?

The second research question builds on RQ1 and focuses on identifying homogeneous groups of regions. It enables the determination of which regions exhibit similar unemployment trends and share similar characteristics. It is important for improving regional policy.

RQ2: Which groups of regions exhibit similar unemployment trends, and how do these groups differ in terms of the educational structure of the population?

Data and Methods

Methods

In the following chapter, the data and methods used will be described. The data and their collection will be presented, as well as the methods of data collection and processing.

Data and Data Collection

For the processing and analysis of the obtained data, the method of hierarchical cluster analysis will be used, which represents one of the most commonly applied methods of multivariate statistical analysis. Its main objective is to identify groups of objects that are similar to each other in terms of selected indicators and, conversely, different from other groups. The method thus makes it possible to reveal the natural structure of the data without prior knowledge of the number or nature of the groups.

In this paper, hierarchical cluster analysis will be applied to identify structural similarities and differences between individual units based on selected socio-economic indicators, particularly those related to the labor market, employment, and unemployment. The aim is to create clusters of regions (or other analyzed entities) that share similar characteristics within key economic and social factors. The obtained results of the hierarchical cluster analysis will make it possible to better understand the spatial distribution and relationships between individual areas, identify regions with similar development trends, and also reveal possible disparities within the examined dataset. The method will contribute to a detailed understanding of the data and to the formulation of conclusions and recommendations.

To measure the distance between individual objects, Euclidean distance will be used, which is one of the most commonly applied measures in multivariate analysis.

The following formula will be used for the calculation:

$$d_{ij} = \sqrt{\sum_{k=1}^{n} (x_{ik} - x_{jk})^2} \tag{1}$$

where:

d_{ij} – distance between regions i and j

x_{ik}, x_{jk} – values of variable k for individual regions

n – number of variables (GeeksforGeeks, 2025)

With regard to the clustering method itself, Ward's method will be applied, as it minimizes the loss of information when merging groups and ensures the formation of the most homogeneous clusters possible. This approach makes it possible to effectively reveal natural relationships between objects and provides a reliable basis for their further interpretation. The result is a dendrogram, which graphically represents the hierarchical structure of relationships between objects and allows for easy visual identification of the most similar units. The optimal number of clusters will be determined by a combination of visual interpretation of the dendrogram and calculation of the silhouette coefficient:

$$s(i) = \frac{b(i) - a(i)}{max\{\mathrm{a(i)}, \mathrm{b(i)}\}} \tag{2}$$

where:

a(i) – average distance of object i to other objects within the same cluster

b(i) – average distance to the nearest neighboring cluster (AMSE Conference, 2018)

For calculations and visualization, MS Excel will be used.

Procedure

1. Data collection: Downloading data from public databases of the Czech Statistical Office (CZSO) for the period 2009-2024 (always valid as of December 31 of the given year) and applying content analysis
2. Data processing: Application of hierarchical cluster analysis, specifically Euclidean distances and Ward's method
3. Evaluation: Evaluation of the dendrogram and silhouette coefficient
4. Interpretation of results: Description of the resulting groups of regions and identification of differences in unemployment development

Results

In the Results chapter, which represents the output of the chosen method, the results of the conducted cluster analysis of the regions of the Czech Republic will be presented in detail and clearly. The analysis focuses on evaluating the similarity of unemployment trends over the period 2009-2024.

Cluster analysis

For the implementation of the cluster analysis, the input data consisted of a time series of the share of unemployed persons in individual regions of the Czech Republic over the period 2009-2024 (see Table 1).

Table 1: Share of Unemployed Persons in the Years 2009-2024

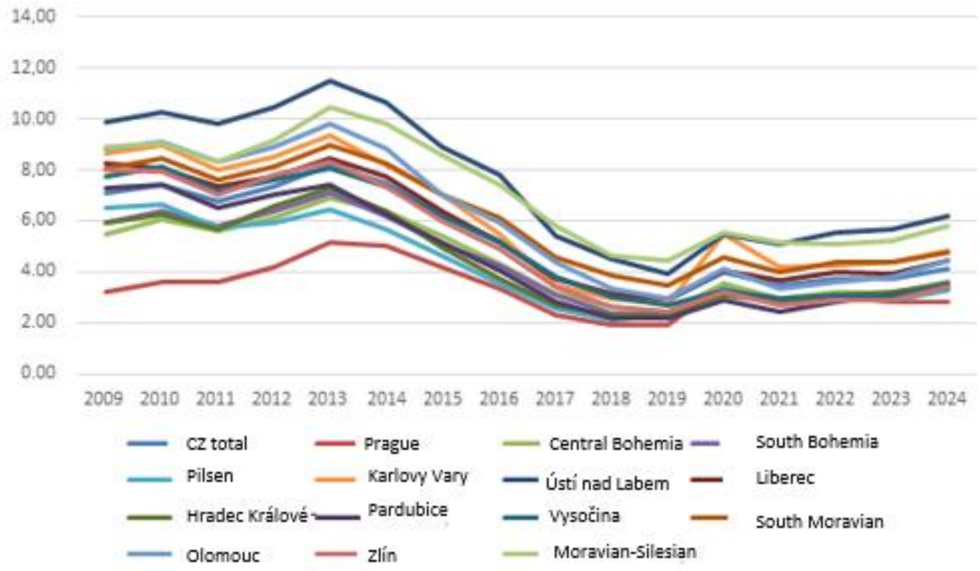
Region / Territory	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Czech Republic total	7.12	7.40	6.77	7.37	8.17	7.46	6.24	5.19	3.77	3.07	2.87	4.02	3.49	3.72	3.73	4.10
Prague	3.24	3.61	3.59	4.16	5.14	05.03	4.20	3.35	2.34	1.93	1.90	3.51	2.76	3.04	2.80	2.80
Central Bohemian	5.51	6.09	5.62	6.13	6.90	6.36	5.41	4.31	3.17	2.64	2.44	3.52	2.98	3.23	3.17	3.36
South Bohemian	5.92	6.39	5.81	6.38	7.10	6.20	5.07	4.28	3.09	2.38	2.31	3.19	2.82	2.98	3.12	3.60
Plzeň	6.50	6.64	5.75	5.94	6.45	5.70	4.62	3.56	2.55	2.12	2.33	3.36	2.78	2.94	2.90	3.26
Karlovy Vary	8.66	8.94	7.98	8.51	9.33	8.21	7.06	5.45	3.47	2.93	2.74	5.45	4.18	4.24	4.38	4.85
Ústí nad Labem	9.87	10.23	9.79	10.47	11.47	10.67	8.91	7.79	5.39	4.50	3.90	5.46	5.08	5.54	5.66	6.21
Liberec	8.29	8.06	7.34	7.75	8.46	7.72	6.36	5.17	3.76	3.18	2.95	4.06	3.66	3.97	3.93	4.46
Hradec Králové	5.96	6.28	5.68	6.55	7.31	6.36	4.96	3.76	2.72	2.31	2.38	3.11	2.83	3.10	3.19	3.56
Pardubice	7.32	7.45	6.50	7.03	7.45	6.22	5.14	4.04	2.83	2.19	2.20	2.92	2.45	2.86	3.10	3.44
Vysočina	7.72	8.10	7.16	7.63	8.05	7.35	6.22	5.17	3.80	3.02	2.70	3.31	2.99	3.08	03.05	3.49
South Moravian	8.05	8.45	7.61	8.15	8.94	8.25	7.01	6.11	4.60	3.86	3.48	4.55	4.02	4.36	4.37	4.74
Olomouc	8.86	9.08	8.33	8.93	9.79	8.82	7.01	5.94	4.35	3.37	2.94	4.11	3.35	3.63	3.81	4.43
Zlín	7.98	7.91	7.00	7.82	8.34	7.36	5.98	4.92	3.43	2.61	2.43	3.22	2.73	2.89	2.88	3.41
Moravian-Silesian	8.88	9.04	8.31	9.18	10.47	9.80	8.56	7.45	5.77	4.65	4.44	5.55	5.14	5.12	5.23	5.82

Source: Own.

Table 1 shows the share of unemployed persons in the years 2009-2024 (in %). This table was essential for conducting the entire cluster analysis; therefore, it is considered important to present it in this paper. The time series clearly indicates that, in all regions of the Czech Republic, there was a significant decrease in unemployment after 2009. Specifically, following the period of the economic crisis between 2009 and 2013, there was a gradual improvement in the labor market. This improvement peaked in the years 2018-2019, when the share of unemployed persons reached its lowest values. This positive trend was temporarily disrupted in 2020 in connection with the COVID-19 pandemic. However, the subsequent economic recovery once again led to a slight decline in unemployment.

For better visualization of the share of unemployed persons in the years 2009-2024, see Graph 1 below. Although this graph presents the same indicator as Table 1, it provides a clearer and more intuitive understanding.

Graph 1: Share of Unemployed Persons in the Years 2009-2024



Source: Own.

In terms of individual regions, the lowest share of unemployed persons is found in the Capital City of Prague, where unemployment has consistently remained below the national average. In 2024, the share of unemployed persons was only 2.8%. Low values are also observed in the Central Bohemian, Pardubice, South Moravian, and Zlín regions. These regions showed a stable development over time.

On the contrary, the highest shares of unemployed persons were consistently recorded in the Ústí nad Labem, Moravian-Silesian, and Karlovy Vary regions. Despite the overall decline, unemployment levels in these regions remained above the Czech Republic's average. The South Bohemian, Plzeň, Hradec Králové, Olomouc regions, and the Vysočina region were characterized by relative stability without significant fluctuations.

Despite the overall improvement in the labor market situation across the country, significant differences between individual regions persisted. Economically stronger regions achieved low unemployment rates, while structurally weaker regions remained below average in terms of unemployment in the long term.

Application of Euclidean Distance and Ward's Method

Table 2 below shows the determination of Euclidean distances. The green color indicates regions with a similar share of unemployed persons, while the red color indicates regions with differing shares of unemployed persons. Subsequently, Ward's method was applied to merge individual groups. With the help of this method, the most homogeneous clusters possible were formed.

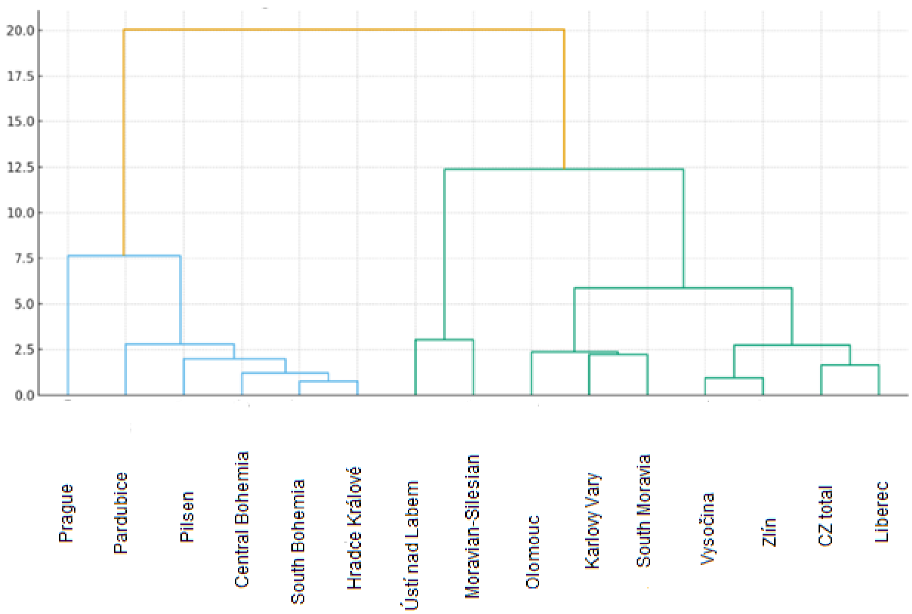
Table 1: Euclidean distance

Region / Territory	Czech Republic total	Prague	Central Bohemian	South Bohemian	Plzeň	Karlovy Vary	Ústí nad Labem	Liberec	Hradec Králové	Pardubice	Vysočina	South Moravian	Olomouc	Zlín	Moravian-S.
Czech Republic total	0	8.975988	3.716903	3.586312	4.583597	3.747635	9.547617	1.649593	3.776245	3.284197	1.768558	3.066558	4.113531	2.250915	7.34022
Prague	8.975988	0	5.343949	5.777177	5.52721	12.37345	18.30007	10.649593	5.764792	7.588748	9.531859	11.87012	13.00898	9.470283	15.8287
Central Bohemian	3.716903	5.343949	0	0.941231	2.01283	7.264136	13.21201	5.20821	1.286811	2.888137	4.238575	6.707102	7.705227	4.286665	10.8843
South Bohemian	3.586311	5.777177	0.941231	0	1.593583	7.065185	13.09308	4.957988	0.764484	2.128998	3.877109	6.613853	7.418809	3.802587	10.8734
Plzeň	4.583597	5.52721	2.01283	1.593583	0	7.747491	14.00658	5.705204	1.565935	2.309475	4.642551	7.535223	8.252682	4.471257	11.8495
Karlovy Vary	3.747634	12.37345	7.264136	7.065185	7.747491	0	6.577035	2.505887	7.142789	6.140267	4.154097	2.240673	2.354579	4.418902	5.02189
Ústí nad Labem	9.547616	18.30007	13.21201	13.09308	14.00658	6.577035	0	8.337211	13.21995	12.27201	9.81403	6.609022	6.198863	10.19924	3.03656
Liberec	1.649592	944793	5.20821	4.957988	5.705204	2.505887	8.337211	0	5.07873	4.085509	2.075795	2.121182	2.889359	2.499876	6.3561
Hradec Králové	3.776245	5.764792	1.286811	0.764484	1.565935	7.142789	13.21995	5.07873	0	2.142052	4.092377	6.806417	7.543304	3.915379	11.0487
Pardubice	3.284197	7.588748	2.888137	2.128998	2.309475	6.140267	12.27201	4.085509	2.142052	0	2.798719	6.028658	6.313671	2.427382	10.3574
Vysočina	1.768558	9.531859	4.238575	3.877109	4.642551	4.154097	9.81403	2.075795	4.092377	2.798719	0	3.646903	3.838615	0.946189	7.87605
South Moravian	3.066558	11.87012	6.707102	6.613853	7.535223	2.240673	6.609022	2.121182	6.806417	6.028658	3.646903	0	2.331854	4.246068	4.38154
Olomouc	4.113531	13.00898	7.705227	7.418809	8.252682	2.354579	6.198863	2.889359	7.543304	6.313671	3.838615	2.331854	0	4.099378	4.84979
Zlín	2.250915	9.470283	4.286665	3.802587	4.471257	4.418902	10.19924	2.499876	3.915379	2.427382	0.946189	4.246068	4.099378	0	8.39334
Moravian-Silesian	7.34022	15.8287	10.8843	10.8734	11.84946	5.021895	3.036559	6.356095	11.0487	10.35739	7.876052	4.381538	4.84979	8.393336	0

Source: Own.

After applying the Euclidean distance, the individual clusters can also be clearly visualized using a dendrogram (see Graph 1)

Graph 1: Dendrograph



Source: Own.

Based on the dendrogram, it was observed that the regions clustered into three natural groups. This classification was further confirmed by the calculation of the silhouette coefficient, which showed the highest value precisely at three clusters. The silhouette coefficient ranged between 0.35 and 0.45, indicating a moderate level of group homogeneity, as well as sufficiently clear separation between the individual clusters.

Resulting Clusters of Regions

Based on the results of the analysis, it was found that the regions of the Czech Republic can be divided into three clusters according to the development of the share of unemployed persons in the period 2009-2024. Each of these clusters exhibited a similar trend in the development of unemployment shares, while at the same time differing from the others in terms of level and stability of values.

Cluster 1 included regions with long-term low and stable unemployment, such as the Capital City of Prague, Central Bohemian, Pardubice, South Moravian, Zlín, and Liberec regions.

Cluster 2 consisted of regions with an average level of unemployment and relatively stable development. This group included the South Bohemian, Plzeň, Hradec Králové, Vysočina, and Olomouc regions. This cluster is characterized by industrial and agricultural activities; however, the labor market is less dynamic.

Cluster 3 comprised regions with the highest levels of unemployment, namely the Karlovy Vary, Ústí nad Labem, and Moravian-Silesian regions. These regions have long faced structural problems in the labor market, a lower share of highly educated population, and a higher proportion of manual occupations.

Linking Clusters with the Educational Level of the Population (Complementary Characteristic)

Table 2: Education structure of the population

Education level	Prague	Central B.	South B.	Plzeň	Karlovy V.	Ústí n. L.	Liberec	Hradec K.	Pardubice	Vysočina	South M.	Olomouc	Zlín	Moravian-S.
Share of persons aged 15+	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
No education	0.4	0.6	0.6	0.7	1.3	1.3	0.8	0.6	0.7	0.5	0.5	0.7	0.6	0.8
Primary (incl. unfinished)	8.3	12.9	13.5	14.0	18.4	18.2	14.7	13.4	13.3	12.9	12.7	13.5	13.6	14.7
Secondary vocational (without GCSE)	18.1	32.2	35.4	35.2	37.5	36.7	36.7	36.0	36.9	38.3	31.6	35.3	36.2	35.6
Full secondary general (with GCSE)	16.1	14.3	13.0	13.4	13.3	12.9	13.3	12.9	12.5	12.5	13.1	13.1	12.9	12.4
Full secondary technical (with GCSE)	15.8	17.3	17.0	17.0	15.0	15.8	16.1	17.6	17.4	17.1	16.1	16.7	16.4	16.3
Follow-up courses	3.0	2.9	17.0	2.6	2.5	2.5	2.8	3.1	2.9	2.9	2.8	2.7	2.8	2.6
Higher professional (conservatory)	2.4	1.9	2.8	1.7	1.4	1.3	1.5	1.7	1.8	1.7	1.6	1.5	1.3	1.2
University - Bachelor's	7.3	3.7	1.7	3.6	2.6	2.8	3.2	3.2	3.2	3.3	4.2	3.4	3.5	3.6
University - Master's	26.1	13.4	3.6	11.2	7.7	8.2	10.5	10.9	10.8	10.4	16.1	12.4	12.3	12.2
University - Doctoral	2.5	0.8	11.7	0.6	0.3	0.3	0.5	0.6	0.6	0.4	1.4	0.8	0.5	0.6

Source: ČSÚ, 2021.

Table 3 presents the percentage distribution of individual levels of educational attainment. This complementary characteristic was linked to the individual clusters and helped to create a more comprehensive picture of unemployment within these clusters.

Cluster 1 (Capital City of Prague, Central Bohemian, Pardubice, South Moravian, Zlín, Liberec regions):

This group is characterized by a higher proportion of individuals with tertiary education (particularly in Prague and the South Moravian region), as well as a significant share of individuals with secondary vocational education (with an apprenticeship certificate). Cluster 1 thus represents regions with a more balanced educational structure—a high proportion of vocationally trained individuals alongside an above-average share of university graduates. These regions consistently achieve lower unemployment rates, to which the educational structure contributes.

Cluster 2 (South Bohemian, Plzeň, Hradec Králové, Vysočina, Olomouc regions):

In all these regions, secondary education without a school-leaving examination (vocational training) predominates, often complemented by a higher proportion of individuals with full secondary vocational education with a school-leaving examination (approximately 16-17%). These regions exhibit a stable but less diversified educational structure compared to Cluster 1. However, this structure corresponds to their economic orientation, as industry and technical professions prevail.

Cluster 3 (Karlovy Vary, Ústí nad Labem, Moravian-Silesian regions):

These regions are characterized by the lowest proportion of tertiary-educated individuals (approximately 7-10%) and a high share of individuals with secondary education without a school-leaving examination (around 36-38%). The high proportion of individuals with lower levels of education, such as basic education or secondary education without a school-leaving examination, may be one of the factors contributing to persistent labor market problems in these regions. In terms of educational structure, these are regions where the workforce is predominantly concentrated in manual and technical occupations.

In all regions of the Czech Republic, with the exception of Prague, secondary education without a school-leaving examination (vocational training) was the most prevalent. This type of education represents the largest group within the population aged 15 and over, accounting for approximately 35-38% in most regions. Only in Prague did tertiary (master's level) education dominate, reaching 36.1%, which clearly distinguishes the capital city from other regions (see Table 3).

Discussion

RQ1: How has unemployment evolved in the regions of the Czech Republic between 2009 and 2024?

The results of the cluster analysis demonstrated that the development of unemployment across the regions of the Czech Republic in the period 2009-2024 is not homogeneous. Regional differentiation is significant and long-term stable. Regions that exhibited higher unemployment at the beginning of the observed period, such as the Ústí nad Labem and Moravian-Silesian regions, remained among those with the highest unemployment levels in subsequent years. In contrast, regions such as the Capital City of Prague, the Plzeň region, and the South Bohemian region consistently showed the lowest values.

The development of unemployment thus indicates that unemployment is not a short-term fluctuating phenomenon, but rather has a structural character that does not change significantly over time. The results confirm that regional differences exhibit persistence and are not merely a reflection of economic cycles. This trend corresponds with the conclusions of Kurilo (2021), who identifies institutional and structural determinants as key factors of regional unemployment. Similarly, the findings of Gil-Alana et al. (2024) on the long memory of time series suggest that unemployment tends to maintain its levels over time, which is also evident in the regions of the Czech Republic.

The results further indicate that regions with weaker economies respond more slowly to economic recovery, as seen in the Ústí nad Labem and Moravian-Silesian regions. This finding is consistent with the principle of hysteresis, as examined by Doganer (2022).

Additionally, it was found that significant regional disparities may also influence migration flows, leading to an outflow of economically active population.

The results confirm that the development of unemployment is long-term, stable, and closely linked to the structural characteristics of regions rather than being a cyclically variable process. At the same time, they highlight the important role of regional socio-economic inequalities, which are not solely of a macroeconomic nature.

RQ2: Which groups of regions exhibit similar unemployment trends, and how do these groups differ in terms of the educational structure of the population?

The conducted cluster analysis identified three main clusters of regions in the Czech Republic with distinct unemployment trends. These clusters reflect socio-economic and educational differences among individual regions.

Cluster 1 is characterized by low unemployment and a high level of education and includes Prague, the Central Bohemian region, and the Plzeň region. It is marked by a stable economy and a higher proportion of tertiary-educated population. These regions have a strong economic base and a highly adaptable workforce. This result corresponds with the findings of Fleka et al. (2022) and Mulero and Garcia-Hiernaux (2022), which confirm that high-quality working conditions, digitalization, and labor mobility contribute to better employment outcomes and lower unemployment.

Cluster 2 is characterized by stability and includes regions such as Vysočina, Zlín, South Bohemian, and Pardubice. These regions exhibit average unemployment levels, relatively stable development, and a slightly increasing share of higher-educated population.

Cluster 3 is characterized by the highest unemployment and lower levels of education and includes the Ústí nad Labem, Moravian-Silesian, and Karlovy Vary regions. Common characteristics include structural unemployment, lower educational attainment, and historical economic burdens such as the decline of heavy industry and low economic growth.

These findings are consistent with Ahn (2023), who emphasizes that regions with longer unemployment duration tend to exhibit weaker structural labor market conditions.

From the author's perspective, the results demonstrate that education is one of the key factors differentiating groups of regions. Regions with higher levels of education tend to have lower unemployment, greater adaptability, and more stable labor markets. This confirms the findings of Riva et al. (2021), who argue that education contributes to greater job stability, as well as Harmannssonová et al. (2024), who state that the expansion of tertiary education can reduce youth unemployment.

Compared to previous authors, who predominantly used econometric models, this study employed cluster analysis, which made it possible to reveal hidden structures in the data and assign regions into homogeneous groups. The results thus provide a new perspective on regional differentiation in unemployment and demonstrate that unemployment development across Czech regions is neither homogeneous nor random, but rather follows long-term patterns, with the educational structure of the population being an important factor influencing unemployment trends. The findings are consistent with and confirm the conclusions of the aforementioned authors.

Conclusion

The aim of this paper was to compare the development of unemployment across the regions of the Czech Republic between 2009 and 2024 and, using hierarchical cluster analysis, to identify similarities and differences among individual regions. The research questions were answered, and the objective of the study was achieved.

The results indicate that the development of unemployment across the regions of the Czech Republic is not homogeneous but exhibits strong and long-term regional differentiation.

Regions with high unemployment at the beginning of the observed period maintained this status in subsequent years, while economically stronger regions have consistently demonstrated low and stable unemployment. This trend is particularly evident in the Capital City of Prague, as well as in the Plzeň and Central Bohemian regions. The cluster analysis thus identified three groups of regions characterized by different unemployment trends.

The first cluster includes regions with low and stable unemployment, the second cluster consists of regions with a medium and relatively stable level of unemployment, and the third cluster comprises regions facing persistently high unemployment. Using the selected complementary characteristic—namely the educational structure—it was demonstrated that regions with a higher proportion of tertiary-educated individuals exhibit lower unemployment than regions with lower levels of educational attainment.

The results showed that the educational structure of the population is one of the key factors distinguishing the groups of regions and influencing regional differences in unemployment. Education represents not only an individual advantage but also a regional competitive advantage. It helps shape long-term labor market development and may contribute to reducing regional disparities.

A limitation of this research is that unemployment is influenced by a number of additional factors, such as economic structure or transport accessibility, which could not be included in the analysis. However, these limitations do not diminish the relevance of the findings, which can be considered both valid and valuable. The contribution of this study lies in providing a comprehensive quantitative perspective on regional differences in unemployment over a long time period. The findings may be useful for regional development experts seeking ways to better target support toward structurally disadvantaged regions.

References

Adebayo, T. S., Olanrewaju, V. O., Ozkan, O., & Ali, S. (2025). How Does Digital Technology Influence Natural Resource Use: A Global Perspective. *Computational Economics 66*(4), 3567–3589. https://doi.org/10.1007/s10614-024-10800-4

Ahn, H. J. (2023). Duration Structure of Unemployment Hazards and the Trend Unemployment Rate. *Journal of Economic Dynamics and Control 151*, 104664. https://doi.org/10.1016/j.jedc.2023.104664

Albertini, M., & Piccitto, G. (2022). Linked Generations: Child's Transition Into Unemployment and Parents' Mental Well-Being. *European Sociological Review 39*(4), 501-515. https://doi.org/10.1093/esr/jcac053

Amse Conference Eu. (2018). [Název příspěvku/prezentace]. *Amse Conference* 10. https://www.amse-conference.eu/old/2018/wp-content/uploads/2018/10/%C5%98ezankov%C3%A1.pdf

Bussi, D., Piazzoni, C., Pancheva, M. G., & Lucchini, M. (2025). The Influence of Social Class of Origin on Labor Market Entry and the Mediating Role of Education in Italy. *Frontiers in Sociology 10*. https://doi.org/10.3389/fsoc.2025.1585459

Český statistický úřad [Czech Statistical Office]. (2024). Podíl Nezaměstnaných [Share of Unemployed Persons]. ČSÚ [CZSO]. https://csu.gov.cz/cr_od_roku_1989_podil_nezamestnanych

Český statistický úřad [Czech Statistical Office]. (2021). Vzdělanostní Struktura Obyvatelstva Podle Výsledků Sčítání Lidu [Educational Structure of the Population According to Census Results]. ČSÚ [CZSO]. https://csu.gov.cz/docs/107508/965f807f-eeb4-afc3-c7fe-7ea958415863/17023224.pdf

Český statistický úřad [Czech Statistical Office]. (2025). Zaměstnanost a Nezaměstnanost [Employment and Unemployment]. ČSÚ [CZSO]. https://csu.gov.cz/zamestnanost-a-nezamestnanost-vsps

Damaske, S., Frech, A., & Wething, H. (2023). The Life Course of Unemployment: The Timing and Relative Degree of Risk. *Work and Occupations 51*(2), 139-180. https://doi.org/10.1177/07308884231162949

Dhingra, S., & Kondirolli, F. (2023). Jobless and Stuck: Youth Unemployment and COVID-19 in India. *IMF Economic Review 71*(3), 580-610. https://doi.org/10.1057/s41308-023-00205-y

Dinopoulos, E., Heins, G., & Unel, B. (2024). Tariff Wars, Unemployment, and Top Incomes. *Journal of Monetary Economics 148*, 103616. https://doi.org/10.1016/j.jmoneco.2024.103616

Doğaner, A. (2022). Avrupa Birliği Ülkelerinde İşsizlik Histerisi Hipotezinin Doğrusal ve Doğrusal Olmayan Birim Kök Testleriyle Tespiti: 1991-2020 Dönemi. *Istanbul Journal of Economics / İstanbul İktisat Dergisi*, 0-0. https://doi.org/10.26650/istjecon2022-1100547

Flek, V., Hála, M., & Mysíková, M. (2022). The Ins and Outs of Central European Unemployment. *Baltic Journal of Economics 22*(1), 49-67. https://doi.org/10.1080/1406099x.2022.2083306

Geeks For Geeks. (2025). Maths - Euclidean Distance. *GeeksForGeeks*. https://www.geeksforgeeks.org/maths/euclidean-distance/

Gil-Alana, L. A., González-Blanch, M. J., & Poza, C. (2024). Labour Market Mismatches in G7 Countries: A Fractional Integration Approach. *Applied Economics 57*(7), 736-752. https://doi.org/10.1080/00036846.2024.2305620

Hermannsson, K., Scandurra, R., & Graziano, M. (2024). The Effect of Higher Education on Youth Unemployment in European Regions During a Period of Economic Instability. *Journal of Education Finance 49*(4), 447-467. https://doi.org/10.1353/jef.2024.a954741

Jo, Ch., Kim, D. H., & Lee, J. W. (2023). Forecasting Unemployment and Employment: A System Dynamics Approach. *Technological Forecasting and Social Change 194*, 122715. https://doi.org/10.1016/j.techfore.2023.122715

Kurilo, A. E. (2021). Long-Term Trends in Regional Labor Markets in Russia. *Regionology 29*(2), 427-446. https://doi.org/10.150407/2413-1407.115.029.202102.427-446

Lopes, A. S. P. P., & Rebelo, I. S. (2025). Am I Wasting My Time? The Influence of Course Unemployment in Academic Dropout. *Education + Training 67*(4), 493-506. https://doi.org/10.1108/et-01-2024-0039

Mehmataj, N., & Xhindi, N. (2022). Public Expenses in Education and Youth Unemployment Rates-A Vector Error Correction Model Approach. *Economies 10*(12). https://doi.org/10.3390/economies10120293

Mian, L., Hussin, R., Slaninová, G., & Shahzadi, Y. (2022). The Impact of E-education and Innovation on Unemployment Reduction Among Graduates: A Way Forward for Higher Educational Institutes. *Frontiers in Psychology 13*. https://doi.org/10.3389/fpsyg.2022.914104

Mulero, R., & Garcia-Hiernaux, A. (2022). Forecasting Unemployment with Google Trends: Age, Gender and Digital Divide. *Empirical Economics 65*(2), 587-605. https://doi.org/10.1007/s00181-022-02347-w

Novikova, O., Azmuk, N., & Pankova, O. (2022). Assessing Imbalance between Labor Quality and Needs of the Labor Market of Ukraine: Educational Challenges. *European Journal of Sustainable Development 11*(1), 77. https://doi.org/10.14207/ejsd.2022.v11n1p77

Olkeba, A., Dula, T., Gutema, P., Tolossa, D., & Mekuriaw, A. (2023). The Effects of Schooling on Rural Unemployment in Ethiopia. *Cogent Economics & Finance 11*(2). https://doi.org/10.1080/23322039.2023.2273599

Perhoniemi, R., Blomgren, J., & Laaksonen, M. (2023). Identifying Labour Market Pathways After a 30-day-long Sickness Absence – A Three-year Sequence Analysis Study in Finland. *BMC Public Health 23*(1). https://doi.org/10.1186/s12889-023-15895-2

Riva, E., Lucchini, M., & Piazzoni, C. (2021). The Effect of Job Quality on Quality of Life and Wellbeing in Later Career Stages: A Multilevel and Longitudinal Analysis on Older Workers in Europe. *Applied Research in Quality of Life 17*(4), 1993-2015. https://doi.org/10.1007/s11482-021-10021-z

Scribbr. (2023). Content Analysis. *Scribbr*. https://www.scribbr.com/methodology/content-analysis/

Contact address of the authors:

Karolína Egerová, Institute of Technology and Business in České Budějovice, School of Expertness and Valuation, Okružní 5170/10, 37001 České Budějovice, Czech Republic, e-mail: 31202@mail.vstecb.cz

Ing. Jozef Adamko, PhD., MBA, Institute of Technology and Business in Prešov, Faculty of Economics, Management and Marketing, Masarykova 22, 080 01 Prešov, Slovak Republik, e-mail: jozef.adamko@centrum.sk

Development of Wheat Prices and the Development of Selected Wheat-Based Products in the Czech Republic

Natálie Pýchová[1], Viera Mokrišová[2]

[1] Institute of Technology and Business in České Budějovice, School of Expertness and Valuation
[2] Institute of Technology and Business in Prešov, Faculty of Economics, Management and Marketing

Abstract

The aim of this study was to evaluate the long-term price development of selected types of wheat and selected wheat products in the Czech Republic and to predict their future development. To achieve this goal, content analysis of secondary data and time series analysis were used, including basic measures of dynamics and the ARIMA model for forecasting prices twelve months in advance. The results showed that the prices of wheat and wheat products fluctuated during periods but grew in the long term. The ARIMA model indicated a slightly downward trend in future prices for both types of wheat. The research provided a holistic overview of the price development of a key agricultural commodity and its processed range, and can thus contribute to better economic decision-making in the agricultural and food sectors. The study is limited by its dependence on a single source data, the absent seasonal adjustment, and the model's sensitivity to market shocks, creating room for expanding the analysis.

Keywords: Agricultural commodities, cereal prices, wheat market, price development, time series analysis, ARIMA, Czech Republic.

Introduction

Agriculture is the primary basis of livelihood and serves as a fundamental pillar of every country. Farmers face several challenges due to various factors such as water scarcity, undefined pricing resulting from supply and demand, weather uncertainty, and inaccurate yield forecasts (Joshua et al., 2021). Due to increasing demand driven by a continuously growing population (Zhao et al., 2022), it is necessary for agricultural management to represent a viable strategy for addressing the growth in crop production (E. Zhang et al., 2025).

Fluctuations in agricultural commodity prices affect both supply and demand (Gu et al., 2022) and have a significant impact on people's daily lives as well as on the inputs and outputs of agricultural production. For consumers, excessive price increases represent a substantial burden on food expenditures, which negatively affects their overall well-being. For farmers, large price fluctuations increase production uncertainty, thereby raising the level of risk they must manage. As a result, accurate forecasting of agricultural commodity prices is crucial for agricultural authorities to make informed decisions and ensure the proper functioning of the socio-economic system (D. Zhang et al., 2020).

Wheat is one of the most important crops in the world (Chen et al., 2025), as also confirmed by Sun et al. (2023) and Li and Li (2022). It is a cereal grown worldwide and plays a crucial role in the global trade market, as it is a key agricultural commodity of the 21st century (Sun et al., 2023). According to Y. Zhang and Li (2022), it is a staple food for approximately 40% of the world's population. The stability of wheat production is therefore closely linked to national food security, sustainable agricultural development, and the livelihoods of millions of people (Sukanya & Babu, 2025).

For this reason, one of the current goals of modern agriculture is to ensure consistent and sustainable yields of this crop, which, due to its high nutritional value and versatility, forms a fundamental component of the human diet and a key commodity in international trade. The cultivation and consumption of wheat have significant economic, social, and cultural implications (Rebouh et al., 2023), and the history of wheat cultivation is as long as the history of civilization itself. Due to its modest cultivation requirements and high nutritional value, wheat rapidly spread from its center of origin (Mesopotamia) across the world (Velimirovic et al., 2021). Today, many types of wheat exist, differing according to regional growing conditions (Donmez, 2024) and climatic exposure (Yue et al., 2025).

Aim of the Study

The aim of this study is to evaluate the development of prices of selected types of wheat and wheat-based products in the Czech Republic over time and to forecast their future development. In line with this objective, the following research questions are defined.

Examining the long-term development of wheat prices makes it possible to identify price trends and differences between food wheat and feed wheat. Evaluating these developments provides insight into market stability and whether both segments are influenced by similar factors, which is important for understanding the price dynamics of this key agricultural commodity in the Czech Republic.

RQ1: How have wheat prices developed from January 2015 to July 2025, and is the trend the same for food wheat and feed wheat?

Forecasting wheat prices is crucial for farmers, traders, and consumers, as it enables better planning of production and business strategies. The importance of this issue lies in supporting effective decision-making in the agricultural sector.

RQ2: What is the expected price development for food wheat and feed wheat over the next 12 months?

Identifying price developments during periods of geopolitical crisis makes it possible to assess how significantly global events have influenced the domestic market for wheat products. Answering this question helps determine the extent of price transmission from primary commodities to final products and is therefore important for evaluating the economic stability of the food market and the impact of crises on end consumers.

RQ3: How have the prices of selected products (food wheat, fine wheat flour type 00 extra, and fine wheat flour) developed from the beginning of the war in Ukraine (January 2021 to July 2025)?

Data and methods

Based on the literature review, data will be collected using content analysis of secondary data from available online sources, and time series analysis will be applied for their subsequent evaluation. These methods will be used to answer all selected research questions.

Data

For data collection, content analysis of secondary data will be used. For the first and second research questions, data will be collected for the period from January 2015 to July 2025, and for the third research question, data from the period January 2021 to July 2025 will be analyzed, i.e., the period since the outbreak of the war in Ukraine. These data are quantitative in nature and are published on a monthly basis for individual years.

The required data can be found on the website of the State Agricultural Intervention Fund (SAIF, 2025), where they are publicly accessible through the following sections: News – Market Information System – Market Reports – Cereals and Oilseeds. The last-mentioned section contains documents in PDF (Portable Document Format) format, which include market reports on cereals, oilseeds, and feed for the selected year.

For the first and second research questions, data from tables titled “Development of Agricultural Producer Prices for Food Wheat and Feed Wheat (CZK/t)” will be analyzed.

Table 1: Descriptive Statistics for RQ1 and RQ2

Commodity	Number of observations	Median	Arithmetic mean	Standard deviation	Min.	Max.
Food wheat	127	4623	4803.15748	1166.974071	3539	8654
Feed wheat	127	4414	4454.19685	1075.223240	3337	8073

Source: Own.

For the third research question, data from the following tables will be used: Comparison of average consumer prices, agricultural producer prices, and industrial producer prices for food wheat and wheat flour (CZK/kg).

Table 2: Descriptive Statistics for RQ3

Commodity	Number of observations	Median	Arithmetic mean	Standard deviation	Min.	Max.
Food wheat	55	5.25	5.745091	1.20510315	4.49	8.65
Wheat flour smooth 00 extra	55	10.72	10.66327	1.94827089	7.46	13.57
Wheat flour smooth	55	16.04	16.77582	3.433166496	12.02	22.72

Source: Own.

Methods

The method used to answer all research questions will be time series analysis. For RQ1 and RQ3, simple measures of time series dynamics will be applied, while RQ2 will be addressed using the Autoregressive Integrated Moving Average (ARIMA) model, which is a classical tool for time series forecasting.

A time series is defined as a sequence of values of an indicator measured at specific time intervals. These intervals are often equivalent (uniform), and therefore can be expressed as follows (Hančlová & Tvrdý, 2003):

$$y_1, y_2, \dots, y_n \; or \; y_t, t = 1, 2, \dots, n, \tag{1}$$

where:

y denotes the analyzed variable,

t is the time variable,

n represents the total number of observations.

Line graphs are used to display time series and for their initial analysis, where the horizontal axis represents the time variable and the vertical axis shows the values of the time series yt. For a more precise evaluation, it is appropriate to use simple measures of time series dynamics, which make it possible to characterize their fundamental behavioral patterns. Among the basic measures of time series dynamics yt, which will be used to answer RQ1 and RQ3, are (Hančlová & Tvrdý, 2003):

- The absolute increment (first difference), which expresses individual changes in time series in terms of increases or decreases, can be calculated using the following formula:

$$\Delta y_t = y_t - y_{t-1}, \qquad t = 2, 3, \dots, n. \tag{2}$$

- To assess the average magnitude of change over the entire observed period, the average absolute increment will be used, which is expressed in the formula as the arithmetic mean of all absolute increments:

$$\overline{\Delta} = \frac{\sum \Delta y_t}{n-1} = \frac{(y_2 - y_1) + \cdots + (y_n - y_{n-1})}{n-1} = \frac{y_n - y_1}{n-1}. \tag{3}$$

- For the relative expression of time series dynamics, the growth rate coefficient is used, which represents the percentage change between selected periods. It is calculated using the following formula:

$$k_t = \frac{y_t}{y_{t-1}}, \quad t = 2, 3, \dots, n. \tag{4}$$

- The average growth coefficient, when multiplied by 100, indicates the percentage of the previous value that the time series reaches on average over the entire observed period. It can be calculated using the following formula:

$$\bar{k} = \sqrt[n-1]{k_2\, k_3\, \dots k_n} = \sqrt[n-1]{\frac{y_2}{y_1}\frac{y_3}{y_2}\frac{y_4}{y_3}\dots\frac{y_n}{y_{n-1}}} = \sqrt[n-1]{\frac{y_n}{y_1}}. \tag{5}$$

The data will be processed in Excel, where tables will be created containing time periods (YYYY-MM) and prices of individual commodities. The data will remain in their original form without rounding, and the above-mentioned formulas will be applied. These tables will subsequently be used to create line graphs illustrating the development of prices of individual wheat types (food wheat and feed wheat) in CZK/t in separate graphs, and selected wheat-based products (food wheat, fine wheat flour type 00 extra, and fine wheat flour) in CZK/kg in a single graph.

For RQ2, time series modeling and forecasting will be conducted using the Autoregressive Integrated Moving Average (ARIMA) model, which is designed to describe time series with stochastic changes in trend (level and slope). The ARIMA model consists of three components, meaning that the current value of the time series depends on past values (AR part – autoregression), past random errors (MA part – moving average), and possibly the difference between the current and past values (I part – integration).

The ARIMA model can be expressed in the following form (Křivý, 2012):

$$\varphi(B)(1-B)^d y_t = \vartheta(B)\varepsilon_{t,} \tag{6}$$

where:

B is the lag operator,

$\varphi(B)$ is the autoregressive polynomial,

$(1 - B)^d$ is the differencing operator,

y_t is the value of the time series at time t,

$\vartheta(B)$ is the moving average polynomial,

ε_t the random component (so-called white noise).

Calculations and visualizations will be performed in RStudio using the packages forecast, zoo, lubridate, and readxl. Data will be imported from Excel using the read_excel() function. The time series will be plotted using the plot() function. The auto.arima() function will automatically select the optimal combination of parameters (AR, I, MA) based on the AIC and BIC criteria. A 12-month forecast will be generated using the forecast() function and visualized graphically together with historical data (black), the forecast (blue), and confidence intervals (grey).

To eliminate short-term fluctuations, the data will be smoothed using a six-month moving average (MA6, rollmean() function from the zoo package). The smoothed series provides a more stable forecast, to which the ARIMA model will be applied again. The predicted values will be exported into a table (write.csv()) containing the average price and a 95% confidence interval for each month.

After applying the methods, the results will be presented using tables and graphs accompanied by statistical descriptions of the time series and interpretations of the individual results of the analysis. The selected methods will be used to evaluate the development of prices of selected types of wheat and selected wheat-based products over the chosen periods. This will provide a clearer understanding of the factors that led to current prices and, based on trend development, allow predictions of whether prices will increase, decrease, or stagnate in the future.

Based on the obtained data and the observed price developments of all commodities and products, it can be expected that the prices of selected types of wheat and wheat-based products will both increase and decrease on a monthly basis over the selected periods. However, over the entire observed period, the average price is expected to show an upward trend.

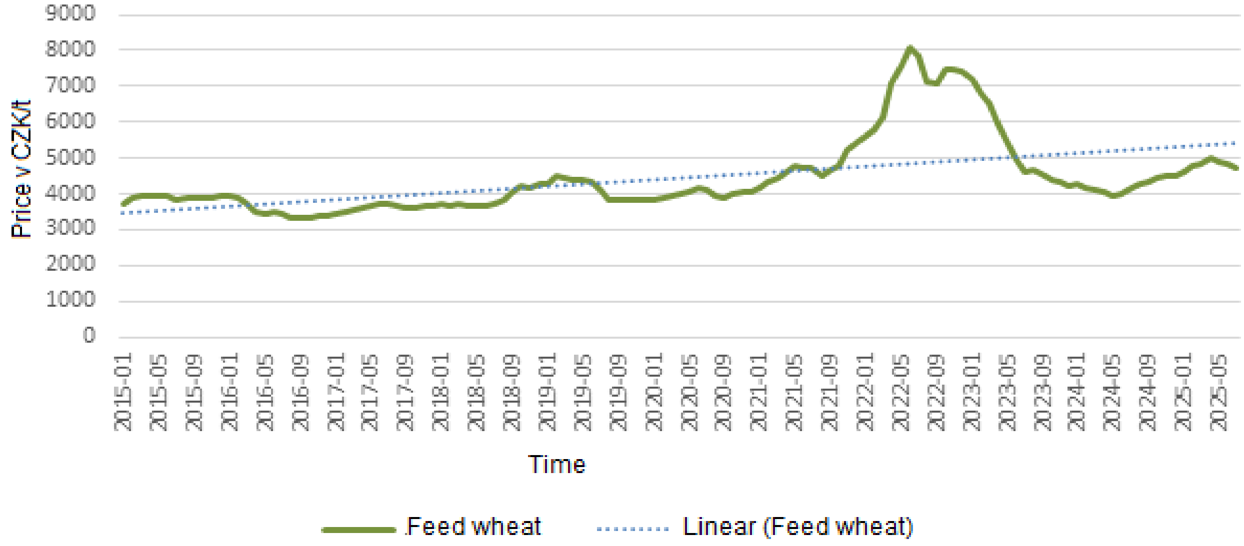
Results

Based on the applied methods, the following results were obtained for the individual research questions.

Within the first research question, RQ1: How have wheat prices developed from January 2015 to July 2025, and is the trend the same for food wheat and feed wheat?, a table was created (see Appendix 1), on the basis of which Graph 1 for food wheat and Graph 2 for feed wheat were developed.

In the first section, attention is focused on the assessment of the development of food wheat prices.

Graph 1: Development of Food Wheat Prices



Source: Own.

Graph 1 shows the development of food wheat prices in the period from January 2015 to July 2025. During this period, prices fluctuate within the range of CZK 3,539 to CZK 8,654 per ton; however, the trend line indicates a long-term upward trend.

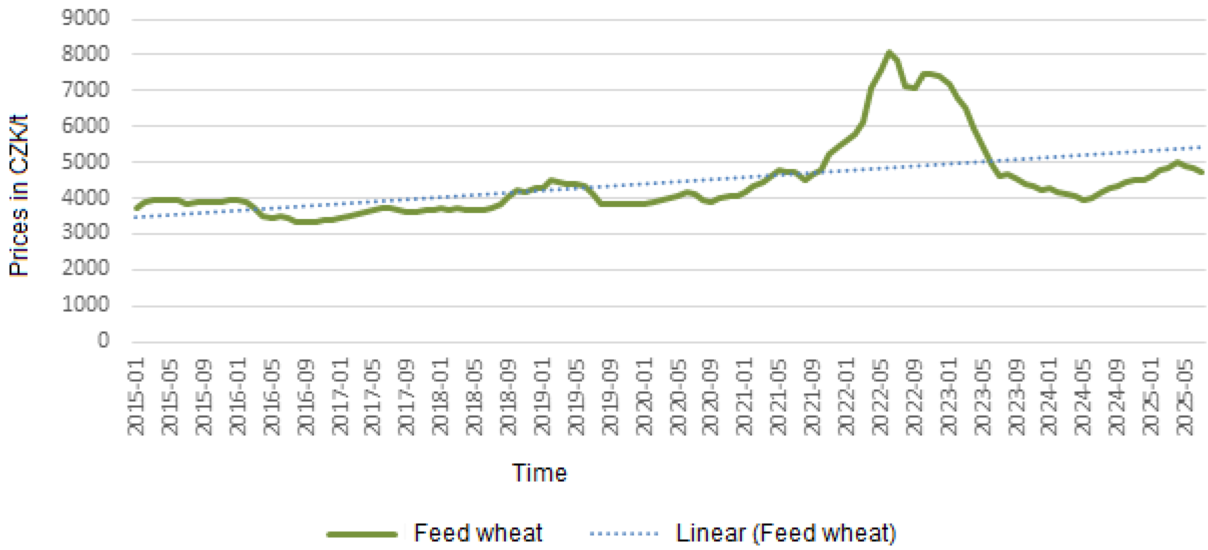
For a more precise assessment of the development, simple measures of time series dynamics were calculated, including absolute increments (see Appendix 2). From these values, calculated using Formula (2), it is evident that monthly prices exhibit typical fluctuations. The average absolute increment, calculated according to Formula (3), amounts to CZK 8.03968254 per ton, indicating that the price of food wheat increased on average.

The same procedure was applied to the growth rate coefficient. After calculation using Formula (4) and conversion into percentages, fluctuations between individual months are again apparent. Using Formula (5), the average growth coefficient was calculated to be 0.1701733%, indicating that food wheat prices increased on average by 0.1701733% over the observed period.

Both the average absolute increment and the average growth coefficient are positive values, confirming that food wheat prices increased over the selected period.

In the second section of the first research question, attention is focused on the development of feed wheat prices.

Graph 2: Development of Feed Wheat Prices



Source: Own.

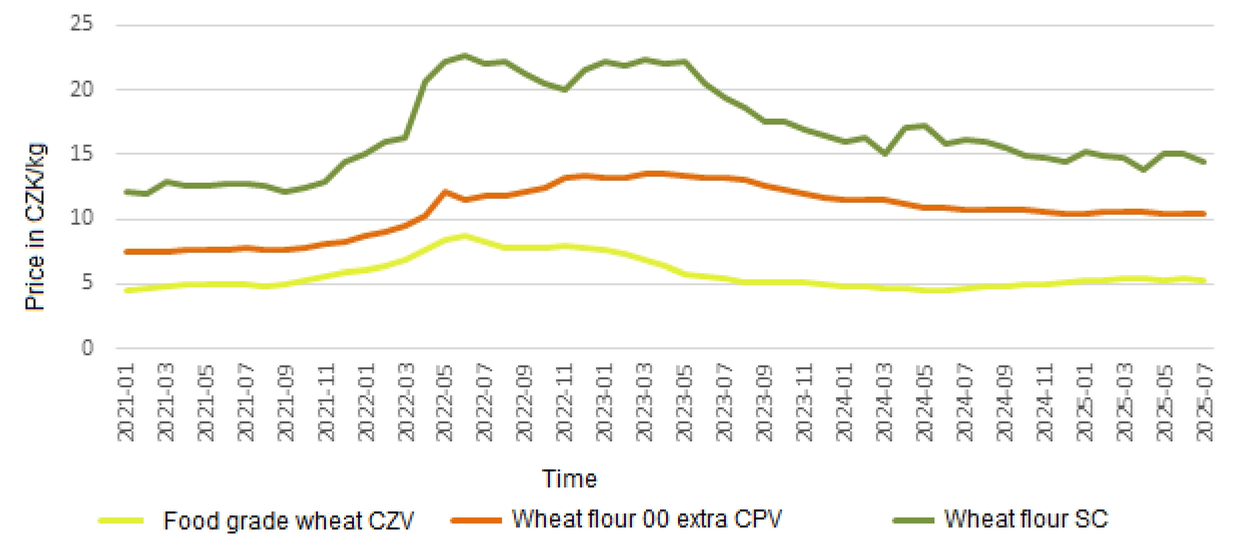
The elements of Graph 2 are the same as in Graph 1, with the only difference being the price values, which range between CZK 3,337 and CZK 8,073 per ton (data from the last column of Appendix 1). The prices of this commodity again fluctuate monthly; however, in the long term, the trend line is also increasing. The development curve is similar to that of food wheat, only at a lower price level.

As in the previous case, the values of absolute increments for feed wheat were calculated and are presented in Appendix 3. These values again fluctuate and often follow the development of food wheat. The average absolute increment amounts to CZK 7.674603175 per ton, indicating that the price of feed wheat increased on average over the observed period. The growth rate coefficient is calculated in the same way (see Appendix 3), and after conversion into percentages, monthly price fluctuations are again evident. Using these values in Formula (5), the result of 0.1822865% was obtained, representing the average growth rate of feed wheat prices.

From the values of absolute increments and the growth coefficient, it is evident that feed wheat prices fluctuate between individual months. At the same time, it is confirmed that prices increased on average during the selected period, as supported by the results of both the average absolute increment and the average growth coefficient.

For the third research question, RQ3: How have the prices of selected products (food wheat, fine wheat flour type 00 extra, and fine wheat flour) developed from the beginning of the war in Ukraine (January 2021 to July 2025)?, a table was created (see Appendix 4), based on which Graph 3 was constructed to illustrate the development of prices of wheat-based products.

Graph 3: Development of Prices of Food Wheat, Fine Wheat Flour Type 00 Extra, and Fine Wheat Flour



Source: Own.

The graph captures the period from January 2021 to July 2025, and the vertical axis displays the prices of individual products in CZK/kg. The values for food wheat are presented as agricultural producer prices, for fine wheat flour type 00 extra as industrial producer prices, and for fine wheat flour as consumer prices. The price range for food wheat is from CZK 4.49 to CZK 8.65/kg, for fine wheat flour type 00 extra from CZK 7.46 to CZK 13.57/kg, and for fine wheat flour from CZK 12.02 to CZK 22.72/kg.

Prices of all three product types fluctuate monthly; however, in the long term, they exhibit an upward trend. These findings are verified using simple measures of time series dynamics.

In the case of food wheat, the values of absolute increments and growth rate coefficients are calculated in the table in Appendix 5. The monthly development again fluctuates. The average absolute increment amounts to CZK 0.014074074/kg, indicating that the price of food wheat increased on average. This result is also confirmed by the average growth coefficient of 0.2900037%.

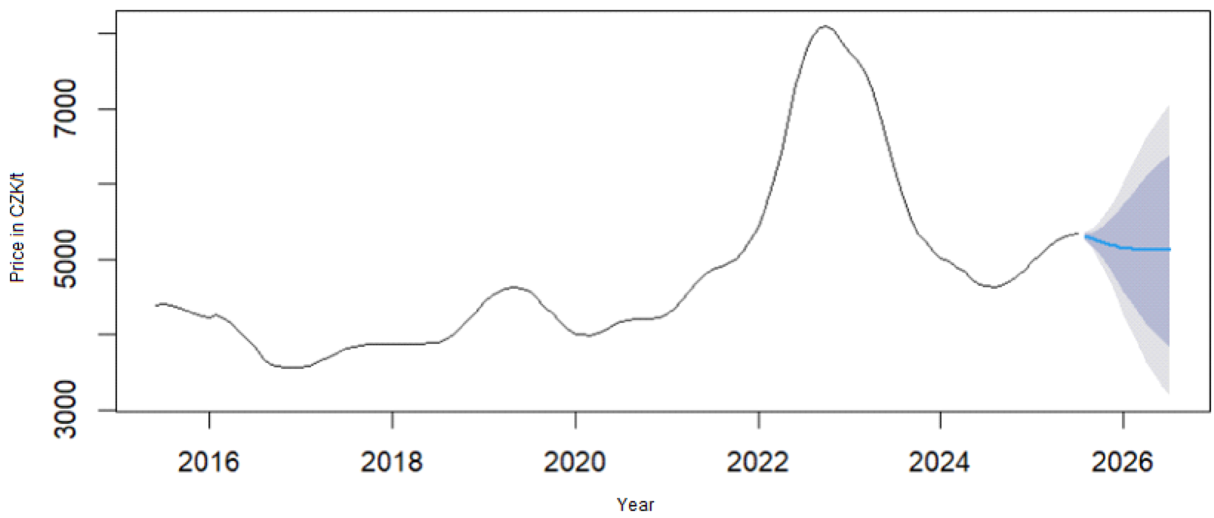
The same calculations, with similar results, were also performed for fine wheat flour type 00 extra. The results (see Appendix 6) show a similar pattern of development as for food wheat. The average absolute increment of this commodity amounts to CZK 0.054259259/kg, confirming its long-term price growth. The average growth coefficient reaches 0.6118813%.

The last selected wheat-based product is fine wheat flour, whose absolute values and growth rate coefficients are calculated in Appendix 7. Both the graph and the calculated values confirm that its price also changes monthly. The average absolute increment amounts to CZK 0.043703704/kg, indicating long-term price growth. The average growth coefficient reaches 0.3302589%.

To answer the second research question, RQ2: What is the expected price development for food wheat and feed wheat over the next 12 months?, time series modeling using the ARIMA model is applied. This method is used on smoothed data for food wheat and feed wheat prices. The forecast is then generated for a twelve-month period, i.e., from August 2025 to July 2026.

Regarding food wheat, its original (grey) and smoothed (black) time series are illustrated in Graph 4. Data smoothing allows for a more accurate identification of the underlying trend.

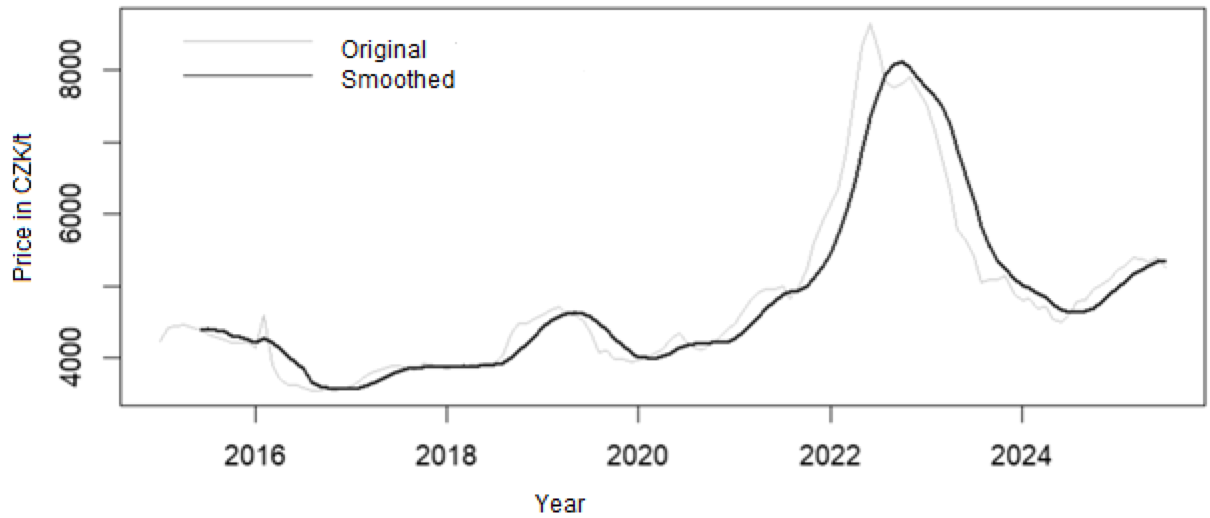
Graph 4: Original vs. Smoothed Time Series (MA6) for Food Wheat



Source: Own.

Based on the smoothed data, a predictive model for the following 12 months (August 2025 to July 2026) is constructed, which is illustrated in Graph 5.

Graph 5: ARIMA Forecast after Data Smoothing (MA6) for Food Wheat



Source: Own.

This graph displays historical data as a black line, the resulting forecast as a blue line, and confidence intervals are represented by grey bands. It is evident that the predicted development of food wheat prices shows a slightly decreasing trend.

Below is Table 3 with the exact predicted values for food wheat in CZK/t.

Table 3: Forecast and 95% Confidence Interval of Food Wheat Prices (CZK/t)

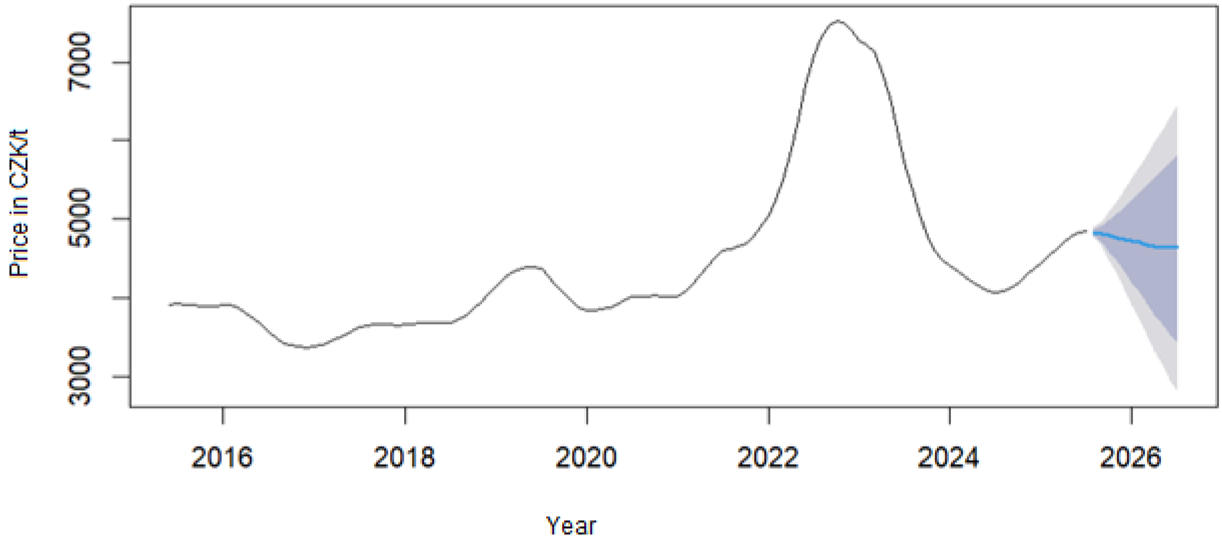
Date	**Predictions (Kč/t)**	**Lower bound of the 95% confidence interval (CZK/t)**	**Upper bound of the 95% confidence interval (CZK/t)**
2025-08	5312.58	5255.55	5369.61
2025-09	5269.33	5115.34	5423.31
2025-10	5234.79	4944.03	5525.55
2025-11	5205.95	4744.50	5667.40
2025-12	5170.39	4510.18	5830.60
2026-01	5149.74	4266.57	6032.91
2026-02	5119.77	4004.51	6235.03
2026-03	5092.75	3737.84	6447.66
2026-04	5064.28	3462.88	6665.68
2026-05	5038.70	3186.84	6890.55
2026-06	5012.31	2906.04	7118.58
2026-07	4988.67	2625.32	7352.01

Source: Own.

The resulting forecast values confirm the graphical representation. The price of food wheat shows a slight downward trend, decreasing from an estimated CZK 5,312.58 per ton in August 2025 to CZK 4,988.97 per ton in July 2026. However, it is necessary to take into account the relatively wide confidence interval, which at the end of the observed period indicates that the actual price could, with 95% probability, lie anywhere between CZK 2,625.32 per ton and CZK 7,352.01 per ton.

A similar procedure is applied to the second commodity within the second research question, feed wheat. The smoothed and original time series are compared in Graph 6.

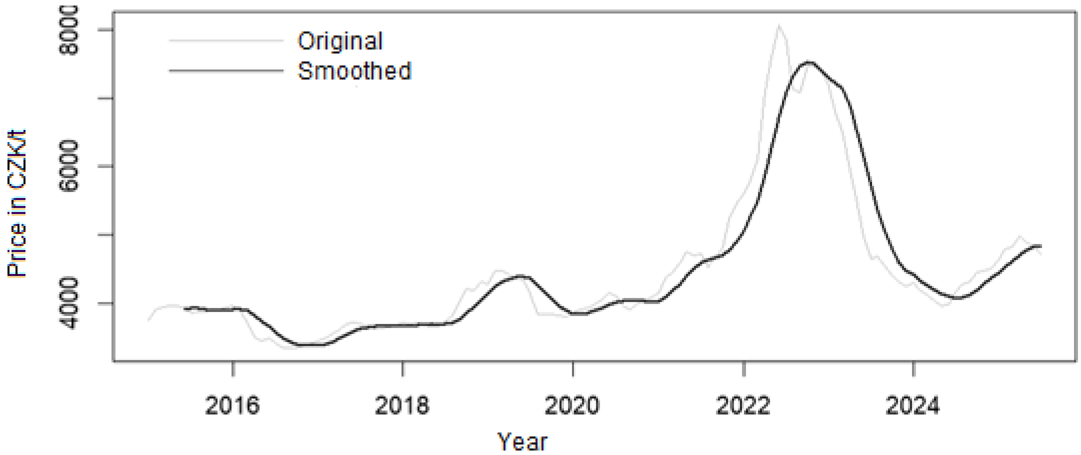
Graph 6: Original vs. Smoothed Time Series (MA6) for Feed Wheat



Source: Own.

Based on these smoothed data, an ARIMA forecasting model is also constructed for the period from August 2025 to July 2026. The results for feed wheat are illustrated in Graph 7.

Graph 7: ARIMA Forecast after Data Smoothing (MA6) for Feed Wheat



Source: Own.

This graph again illustrates historical data (black line), the forecast itself (blue line), and grey bands representing the confidence intervals. The forecast for feed wheat also indicates a slightly decreasing trend. Exact point estimates in CZK/t and confidence intervals are presented in Table 4.

Table 4: Forecast and 95% Confidence Interval of Feed Wheat Prices (CZK/t)

Date	Predictions (Kč/t)	Lower bound of the 95% confidence interval (CZK/t)	Upper bound of the 95% confidence interval (CZK/t)
2025-08	4830.26	4769.24	4891.28
2025-09	4810.00	4647.24	4974.75
2025-10	4789.43	4478.46	5100.40
2025-11	4764.43	4297.38	5231.47
2025-12	4739.33	4110.02	5368.63
2026-01	4719.09	3920.96	5517.23
2026-02	4697.09	3724.19	5670.00
2026-03	4683.86	3529.19	5838.52
2026-04	4672.17	3331.45	6012.88
2026-05	4666.20	3137.28	6195.12
2026-06	4661.28	2941.63	6380.92
2026-07	4668.64	3317.02	6020.26

Source: Own.

In the case of feed wheat as well, the tabulated forecast data confirm the declining trend shown in the graph. The estimated price at the beginning of the forecast period (August 2025) is approximately CZK 4,830.26 per ton and gradually decreases to an estimated value of CZK 4,668.64 per ton (July 2026).

It is also necessary to emphasize the widening confidence interval, which reaches a considerable range by the end of the forecast period. With 95% probability, the price could range between CZK 3,317.02 per ton and CZK 6,020.26 per ton.

Disscusion of results

Based on the obtained results, it is possible to answer the defined research questions.

RQ1: How have wheat prices developed from January 2015 to July 2025, and is the trend the same for food wheat and feed wheat?

The evaluation of time series using basic measures of dynamics showed that the prices of both types of wheat fluctuated significantly on a monthly basis between 2015 and 2025. Both commodities exhibited a very similar long-term development. Although their price levels differed, the trend line and average increments had almost identical characteristics, as the average absolute increment for food wheat was CZK 8.03968254 per ton and CZK 7.674603175 per ton for feed wheat.

It is noteworthy that the COVID-19 pandemic did not significantly affect prices, whereas the geopolitical conflict in Ukraine, which began in 2022, had a noticeable impact and led to a short-term but intense increase in prices.

It is particularly interesting that the similarity between both time series is surprisingly strong, despite the fact that food wheat and feed wheat enter different production chains. This suggests that the Czech market is strongly interconnected with the global grain market, and that price formation is significantly influenced by it. Another factor that may affect these prices is the export orientation of the Czech Republic. As a result, domestic producers may naturally respond to global signals and expectations. The short-term price spike following the outbreak of the war in Ukraine further confirms this interconnection.

These findings are consistent with the conclusions of Martin & Minot (2022), who highlight the long-term growth of global wheat prices and the existence of stable relationships between global and domestic prices. Granados Sanchez et al. (2020) also confirm that basic grain prices increased at the domestic level, which subsequently had a negative impact throughout the entire transformation chain through rising prices of processed products. The impact of the outbreak of the war between Russia and Ukraine on wheat prices is also confirmed, for example, by Xu et al. (2023).

RQ2: What is the expected price development for food wheat and feed wheat over the next 12 months?

Using time series modeling through the ARIMA model and smoothed data, it was found that the forecast for the period from August 2025 to July 2026 indicates a slightly declining trend in prices for both commodities. In both series, there is a gradual decrease in values during the forecast period, while at the same time a widening of confidence intervals is observed. This suggests increasing uncertainty of the predictive model over a longer time horizon.

This development likely reflects market stabilization following the period of extreme price fluctuations between 2021 and 2023. It can be interpreted as a return to more balanced levels rather than a significant price decline. However, it is evident that wheat price formation is currently much more sensitive to external shocks than in the past. The ARIMA model captures this uncertainty through wide confidence intervals, which is an important insight for future users of forecasts.

The difficulty of predicting wheat prices is also highlighted by other authors. Kumari et al. (2025) agree with this statement and identify the interplay between economic trends, environmental variability, unpredictable market conditions, and the lack of reliable data as the main challenges. Cariappa et al. (2020) further argue that wheat production levels in a given country also influence price predictions, finding that expected prices tend to be higher in countries with low or negligible wheat production and lower in countries with higher production.

RQ3: How have the prices of selected products (food wheat, fine wheat flour type 00 extra, and fine wheat flour) developed from the beginning of the war in Ukraine (January 2021 to July 2025)?

The third research question focused on a period significantly influenced by geopolitical events. The results showed that the prices of all three wheat-based products exhibited considerable fluctuations, but overall increased during the period from 2021 to 2025.

From the graphs, absolute increments, and growth rate coefficients, it is evident that prices did not change significantly at the beginning of the observed period, with gradual increases occurring approximately from September 2021. A more pronounced price increase was observed from March 2022. All product categories reached their maximum price levels between May and June 2022, i.e., a few months after the outbreak of the conflict, when disruptions in wheat imports from war-affected regions began to occur.

Not only did prices increase, but in the case of selected wheat-based products, they even grew faster than the price of wheat itself. This amplification of the price shock may have been caused by rising costs of energy, packaging materials, and transportation, which significantly increased processing costs. The sensitivity of the food sector may have been further intensified by logistical complications and high market uncertainty, creating a combination of factors that pushed the prices of these products even higher than those of the primary commodity.

Granados Sanchez et al. (2020) support these findings, stating that the transmission of price shocks to final products is significant. Ferguson & Ubilava (2022) also agree, noting that the outbreak of war in the "breadbasket of Europe" sent major grain prices into an upward spiral. Devadoss & Ridley (2024) further analyzed wheat price developments following the outbreak of the conflict in Ukraine and found that this event led to price increases across all countries by approximately 2%.

The discussion shows that the results of this study are consistent with current research findings on the development of wheat and wheat-based product prices. The chosen methodology of time series analysis and ARIMA-based forecasting proved to be appropriate, transparent, and capable of providing high-quality results. However, it is necessary to consider the limitations of both the data used and the predictive model. Nevertheless, the results represent a relevant and well-interpretable basis for understanding the development of wheat and wheat-based product prices in the Czech Republic.

Conclusion

The aim of this study was to evaluate the development of prices of selected types of wheat and wheat-based products in the Czech Republic over time and to forecast their future development. This objective was achieved through time series analysis using basic measures of dynamics and the ARIMA forecasting model, which enabled a detailed assessment of price developments.

Based on these methods, all defined research questions were successfully answered. For the first research question, it was found that both food wheat and feed wheat prices increased between 2015 and 2025, although their monthly development showed considerable fluctuations. Both commodities exhibited similar trends as well as similar values of increments and growth rates, indicating very similar market behavior. These results are consistent with the literature, which also describes rising grain prices and their transmission into subsequent processing industries.

For the second research question, a forecast of wheat price development for the following 12 months (from August 2025 to July 2026) was developed. The ARIMA model indicated a slightly declining trend in the prices of both commodities, while the accuracy of the forecast was limited by the increasing width of the confidence intervals. This approach demonstrated that the ARIMA model is a suitable tool for short-term forecasting of price time series, as confirmed by other academic studies. At the same time, it was shown that the forecast remains sensitive to external factors not captured by the model.

The third research question focused on the development of wheat and selected wheat-based product prices since the beginning of the conflict in Ukraine. The results showed that the prices of all observed commodities increased significantly after the outbreak of the war, reaching their highest values between May and June 2022. Flour prices increased even faster than wheat prices, which corresponds with findings from studies examining the impact of price shocks on agricultural markets.

The limitations of the research primarily consisted of the use of data from a single source (SAIF), the absence of seasonal adjustment, and the limited ability of the forecasting model to capture unexpected external shocks. Nevertheless, the obtained results were sufficiently reliable to answer the research questions and achieve the aim of the study. Therefore, the defined objective was fully accomplished.

The contribution of this study lies in the detailed evaluation of wheat price developments over a long time period, the identification of the impact of recent crisis events, and the creation of a forecast that may serve as a basis for decision-making by stakeholders in the agricultural and food sectors. The results also demonstrate that price development is complex and sensitive to a range of external factors, which creates opportunities for future research using more advanced models or a broader set of input variables.

References

Akkem, Y., Biswas, S. K., & Varanasi, A. (2023). Smart Farming Using Artificial Intelligence: A Review. *Engineering Applications of Artificial Intelligence, 120*, 105899. https://doi.org/10.1016/j.engappai.2023.105899

Aliu, F., Kucera, J., & Haskova, S. (2023). Agricultural Commodities in the Context of the Russia-Ukraine War: Evidence From Corn, Wheat, Barley, and Sunflower Oil. *Forecasting, 5*(1), 351–373. https://doi.org/10.3390/forecast5010019

Balcilar, M., Sertoglu, K., & Agan, B. (2022). The COVID-19 Effects on Agricultural Commodity Markets. *Agrekon, 61*(3), 239–265. https://doi.org/10.1080/03031853.2022.2078381

Cariappa, A. G. A., Kathayat, B., Karthiga, S., & Sendhil, R. (2020). Price Analysis and Forecasting for Decision Making: Insights From Wheat Markets in India. *Indian Journal of Agricultural Sciences, 90*(5), 139–144.

Chen, H., Ingraffia, R., Schloter, M., Brueggemann, N., & Rillig, M. C. (2025). Effects of Multiple Microplastic Types on Growth of Winter Wheat and Soil Properties Vary in Different Agricultural Soils. *Plants People Planet, 7*(1), 194–203. https://doi.org/10.1002/ppp3.10573

Devadoss, S., & Ridley, W. (2024). Impacts of the Russian Invasion of Ukraine on the Global Wheat Market. *World Development, 173*, 106396. https://doi.org/10.1016/j.worlddev.2023.106396

Donmez, E. (2024). Hybrid Convolutional Neural Network and Multilayer Perceptron Vision Transformer Model for Wheat Species Classification Task: E-ResMLP+. *European Food Research and Technology, 250*(5), 1379–1388. https://doi.org/10.1007/s00217-024-04469-0

Ferguson, S., & Ubilava, D. (2022). Global Commodity Market Disruption and the Fallout. *Australian Journal of Agricultural and Resource Economics, 66*(4), 737–752. https://doi.org/10.1111/1467-8489.12497

Granados Sanchez, M. D. R., Galan Figueroa, J., & Leos Rodrigues, J. A. (2020). Price Volatility in Basic Cereals and Their Impact in Food Security. Mexico, 1995-2018. *Noesis-Revista de Ciencias Sociales y Humanidades, 29*(58), 79–105. https://doi.org/10.20983/noesis.2020.2.4

Gu, Y. H., Jin, D., Yin, H., Zheng, R., Piao, X., & Yoo, S. J. (2022). Forecasting Agricultural Commodity Prices Using Dual Input Attention LSTM. *Agriculture-Basel, 12*(2), 256. https://doi.org/10.3390/agriculture12020256

Hančlová, J., & Tvrdý, L. (2003). Introduction to Time Series Analysis. University of Mining and Technology Ostrava.https://intranet.fd.cvut.cz/department/k611/PEDAGOG/VSM/7_AnalyzaCasRad.pdf

Jiang, F., Ma, X. Y., Li, Y. Y., Li, J. X., Cao, W. L., Tong, J., Chen, Q. Y., Chen, H., & Fu, Z. X. (2023). How Deep Learning Affect Price Forecasting of Agricultural Supply Chain? *Journal of Information Science and Engineering, 39*(4), 809–823. https://doi.org/10.6688/JISE.202307_39

Jiang, W., Zhang, D., Ling, L., Cai, G., & Zeng, L. (2023). Time Series to Imaging-Based Deep Learning Model for Detecting Abnormal Fluctuation in Agriculture Product Price. *Soft Computing, 27*(20), 14673–14688. https://doi.org/10.1007/s00500-023-09121-9

Joshua, V., Priyadharson, S. M., & Kannadasan, R. (2021). Exploration of Machine Learning Approaches for Paddy Yield Prediction in Eastern Part of Tamilnadu. *Agronomy-Basel, 11*(10), 2068. https://doi.org/10.3390/agronomy11102068

Křivý, I. (2012). Time Series Analysis. University of Mining - Technical University of Ostrava. https://web.osu.cz/~Bujok/files/ancas.pdf

Kumari, P., Harshith, N., & Ginige, A. (2025). Integrating Recursive Feature Selection with Automated Machine Learning Framework for Global Wheat Price Prediction. *Journal of Agriculture and Food Research 22*, 102113. https://doi.org/10.1016/j.jafr.2025.102113

Li, B., & Li, J. (2022). Optimized Deep Neural Network and Its Application in Fine Sowing of Crops. *Computational Intelligence and Neuroscience, 2022*. https://doi.org/10.1155/2022/3650702

Martin, W., & Minot, N. (2022). The Impacts of Price Insulation on World Wheat Markets During the 2022 Food Price Crisis. *Australian Journal of Agricultural and Resource Economics, 66*(4), 753–774. https://doi.org/10.1111/1467-8489.12498

Mohammed, S. A., Alkerdi, A., Nagy, J., & Harsanyi, E. (2020). Syrian Crisis Repercussions on the Agricultural Sector: Case Study of Wheat, Cotton and Olives. *Regional Science Policy and Practice, 12*(3), 519–537. https://doi.org/10.1111/rsp3.12222

Mottaleb, K. A., Kruseman, G., & Snapp, S. (2022). Potential Impacts of Ukraine-Russia Armed Conflict on Global Wheat Food Security: A Quantitative Exploration. *Global Food Security-Agriculture Policy Economics and Environment 35*, 100659. https://doi.org/10.1016/j.gfs.2022.100659

Rajpoot, K., Singla, S., Singh, A., & Shekhar, S. (2022). Impact of COVID-19 Lockdown on Prices of Potato and Onion in Metropolitan Cities of India. *Journal of Agribusiness in Developing and Emerging Economies, 12*(3), 386–399. https://doi.org/10.1108/JADEE-04-2021-0099

Rebouh, N. Y., Khugaev, C. V., Utkina, A. O., Isaev, K. V., Mohamed, E. S., & Kucher, D. E. (2023). Contribution of Eco-Friendly Agricultural Practices in Improving and Stabilizing Wheat Crop Yield: A Review. *Agronomy-Basel, 13*(9), 2400. https://doi.org/10.3390/agronomy13092400

Státní zemědělský intervenční fond [State Agricultural Intervention Fund] (SZIF) [SAIF]. (2025). Market News - Cereals and Oilseeds. SZIF [SAIF]. https://szif.gov.cz/cs/zpravy-o-trhu

Sukanya, K., & Babu, S. K. K. (2025). An ARIMA Model Approach for Predicting Wheat Production in India and China. *Sigma Journal of Engineering and Natural Sciences-Sigma Muhendislik Ve Fen Bilimleri Dergisi, 43*(2), 383–390. https://doi.org/10.14744/sigma.2025.00031

Sun, H., Wang, B., Wu, Y., & Yang, H. (2023). Deep Learning Method Based on Spectral Characteristic Reinforcement for the Extraction of Winter Wheat Planting Area in Complex Agricultural Landscapes. *Remote Sensing, 15*(5), 1301. https://doi.org/10.3390/rs15051301

Velimirovic, A., Jovovic, Z., & Przulj, N. (2021). From Neolithic to Late Modern Period: Brief History of Wheat. *Genetika-Belgrade, 53*(1), 407–417. https://doi.org/10.2298/GENSR2101407V

Viana, C. M., Freire, D., Abrantes, P., & Rocha, J. (2021). Evolution of Agricultural Production in Portugal during 1850-2018: A Geographical and Historical Perspective. *Land, 10*(8), 776. https://doi.org/10.3390/land10080776

Xu, Y., Wang, Z., Dong, W., & Chou, J. (2023). Predicting the Potential Impact of Emergency on Global Grain Security: A Case of the Russia-Ukraine Conflict. *Foods, 12*(13), 2557. https://doi.org/10.3390/foods12132557

Yue, J., Yao, Y., Shen, J., Li, T., Xu, N., Feng, H., Wei, Y., Xu, X., Lin, Y., Guo, W., Fu, Y., Qiao, H., Ma, X., & Wang, J. (2025). Winter Wheat Harvest Detection via Sentinel-2 MSI Images. *International Journal of Remote Sensing, 46*(6), 2482–2500. https://doi.org/10.1080/01431161.2025.2452318

Zhang, D., Chen, S., Ling, L., & Xia, Q. (2020). Forecasting Agricultural Commodity Prices Using Model Selection Framework With Time Series Features and Forecast Horizons. *Ieee Access 8*, 28197–28209. https://doi.org/10.1109/ACCESS.2020.2971591

Zhang, E., Liu, Y., Tan, Q., Chen, J., & Pan, T. (2025). Projected Changes in Future Wheat Yield Across China Under CMIP6 Climate Simulations and Agricultural Management Scenarios. *Journal of Cleaner Production, 508*, 145570. https://doi.org/10.1016/j.jclepro.2025.145570

Zhang, Y., & Li, B. (2022). Detection of the Spatio-Temporal Differentiation Patterns and Influencing Factors of Wheat Production in Huang-Huai-Hai Region. *Foods 11*(11), 1617. https://doi.org/10.3390/foods11111617

Zhao, F., Xu, L., Lv, L., & Zhang, Y. (2022). Wheat Ear Detection Algorithm Based on Improved YOLOv4. *Applied Sciences-Basel, 12*(23), 12195. https://doi.org/10.3390/app122312195

Zhuang, J., Xu, S., Li, G., & Zhong, Z. (2022). Intelligent Decision Method of Multi-Agricultural Commodity Model Based on Machine Learning. *International Journal of Pattern Recognition and Artificial Intelligence, 36*(08), 2251003. https://doi.org/10.1142/S021800142251003X

Contact address of the authors:

Bc. Natálie Pýchová, Institute of Technology and Business in České Budějovice, School of Expertness and Valuation, Okružní 5170/10, 37001 České Budějovice, Czech Republic, e-mail: 31322@mail.vstecb.cz

PhDr. Mgr. Viera Mokrišová, PhD., MBA, MBA, Institute of Technology and Business in Prešov, Faculty of Economics, Management and Marketing, Masarykova 22, 080 01 Prešov, Slovak Republik, e-mail: mokrisova@vste.sk

Development and Forecast of Unemployment in the Czech Republic in Comparison with EU Countries

Kateřina Jíchová[1], Jozef Adamko[2]

[1] Institute of Technology and Business in České Budějovice, School of Expertness and Valuation
[2] Institute of Technology and Business in Prešov, Faculty of Economics, Management and Marketing

Abstract

The aim of this thesis was to evaluate the development of unemployment in the Czech Republic, compare it with neighboring countries, and subsequently predict its future development. To achieve this goal, time series analysis, the Prophet prediction model, and correlation measurements supplemented by a graphical representation of the Beveridge curve were used. The results showed that the Czech Republic has long been one of the countries with the lowest unemployment rates in the region, with future developments indicating a slight downward trend and a significantly indirect relationship between unemployment and job vacancies. These findings contributed to a better understanding of the dynamics of the Czech labor market. However, the research is limited by data availability, time constraints, and the dependence of predictions on the stability of the economic environment, which opens up space for further studies focused on other regions or more detailed structural analyses.

Keywords: Unemployment, Czech Republic, European Union, Prophet, Beveridge curve, job vacancies, regional comparisons.

Introduction

One of the main problems that societies face today is unemployment, although its development differs across individual economies. Unemployment is not only an indicator of economic development but also a variable that may delay or prevent real convergence among the member states of the European Union. For this reason, it is essential to understand the determinants of unemployment rate development and the factors that influence it (Sanchez et al., 2023).

Unemployment can be considered a socio-economic phenomenon that occurs in all EU economies and has wide-ranging impacts—it affects sectors of the national economy, various population groups, as well as selected regions of Europe (Korecko & Vravec, 2023). It is also one of the key indicators used to assess the strength and stability of an economy. Accurate understanding and rational use of this indicator play an important role in evaluating the sustainable development of a national economy. The unemployment rate is influenced by many different factors, both subjective and objective, at both microeconomic and macroeconomic levels (Pham et al., 2023). Among the important macroeconomic tools that can influence unemployment is fiscal policy, which enables governments to respond to economic fluctuations (Nguyen, 2022).

However, unemployment also has negative impacts on individuals and society as a whole, as it affects both well-being and health (Malisauskaite et al., 2022). It is widely known that unemployment causes a number of psychosocial problems that may have harmful effects on mental health (Wani & Ahmed, 2024). Albertini & Piccitto (2023) further add that job loss negatively affects not only the individual but also the well-being of their partner and children, making unemployment a problem for entire families.

In the European Union labour market, the free movement of production factors also plays an important role. In the enlarged EU, this has led to migration flows from east to west and from south to north, which has also been reflected in the unemployment rates of individual countries (Moridian et al., 2024). These processes show that unemployment is not only a national issue but also an international one.

Job searching is a natural and important activity that individuals perform at various stages of their lives—for example, when transitioning from school to employment, after job loss, when changing jobs, or when changing careers (van Hooft et al., 2021). The effective functioning of the labour market and the reduction of unemployment therefore contribute not only to economic stability but also to individual well-being.

Unemployment is therefore a crucial indicator reflecting the economic situation and development of societies. Its existence represents a loss of a production factor—labour—and therefore requires careful planning and policy-making aimed at controlling and reducing unemployment (Rafei et al., 2023).

Based on societal demand, the aim of this study is to evaluate the development of unemployment in the Czech Republic, compare it with neighbouring countries, and subsequently predict its future development. The study also includes an assessment of the relationship between unemployment and job vacancies, which reflects the efficiency of the labour market in the Czech Republic.

The study first focuses on comparing the development of unemployment rates in the Czech Republic with its neighbouring countries—Germany, Poland, Austria, and Slovakia. These countries are suitable for comparison not only due to their geographical proximity but also because of their economic interconnections and shared historical context. This first question therefore allows us to determine whether the Czech economy responds to economic fluctuations similarly to its neighbours or whether it exhibits specific characteristics. The research question is as follows:

RQ1: What has been the development of the unemployment rate in the Czech Republic compared to neighbouring countries (Germany, Poland, Austria, and Slovakia) since January 2007?

The second research question focuses on a detailed evaluation of unemployment in the Czech Republic, allowing for an understanding of long-term trends and changes affecting the domestic labour market. The study will subsequently estimate the future development of unemployment and its nonlinear trend over a short-term horizon. The second research question is therefore:

RQ2: What has been the development of the unemployment rate in the Czech Republic since January 1993, and what will be its trend over the next two years?

However, unemployment alone does not always fully reflect labour market efficiency—this is better captured by the relationship between the number of unemployed individuals and the number of job vacancies. Therefore, the final research question focuses on the relationship between these two variables:

RQ3: What is the relationship between unemployment and job vacancies in the Czech Republic since January 2000?

Data and methods

The data necessary to answer all research questions will be collected on a monthly basis using quantitative content analysis from the following sources:

Eurostat (2025) – data on unemployment rates in the Czech Republic and neighbouring countries (Germany, Poland, Slovakia, and Austria) for the period from January 2007 to July 2025.

Czech Statistical Office (2025) – time series of the unemployment rate in the Czech Republic for the period from January 1993 to July 2025.

Ministry of Labour and Social Affairs (2025) – data on the number of unemployed persons and job vacancies for the period from January 2007 to December 2024.

The data are publicly available on the official websites of the respective institutions and will be further described statistically; therefore, it is not necessary to include them in the appendices.

For the evaluation of the obtained data, RStudio and Microsoft Excel 365 will be used. The analysis will include time series analysis and correlation, specifically the Prophet model and measures of time series dynamics—growth rate coefficient and relative increment—as well as Pearson's correlation coefficient.

To compare the development of unemployment between the Czech Republic and its neighbouring countries, time series analysis will be applied, specifically the calculation of the growth rate coefficient and relative increment. The average growth rate will be calculated according to the following formula (Hančlová & Tvrdý, 2003):

$$\bar{k} = \sqrt[n-1]{k_2 * k_2 * \cdots k_n} = \sqrt[n-1]{\frac{y_2}{y_1} * \frac{y_3}{y_2} \cdots * \frac{y_n}{y_n}} = \sqrt[n-1]{\frac{y_n}{y_1}} \tag{1}$$

where:

- n – number of observations in the series,
- y – value of the indicator at time t (unemployment rate).

The relative increment is then expressed by the following equation (Hančlová & Tvrdý, 2003):

$$\delta_t = \frac{\Delta y_t}{y_{t-1}} = \frac{y_t - y_{t-1}}{y_t} = \frac{y_t}{y_{t-1}} - 1 \tag{2}$$

where:

- y – value of the indicator at time t (unemployment rate),
- t – time variable.

The output will consist of a graph showing the development of unemployment rates in individual countries and tables containing values of the average growth rate and relative increment.

For forecasting future unemployment rates, the Prophet model will be used, as it is suitable for processing time series with irregular seasonal fluctuations. This model allows the decomposition of the trend into several components—long-term trend, seasonality, and random variations—and is represented by the following equation (Otexts, 2025):

$$y_t = g(t) + s(t) + h(t) + \varepsilon_t \tag{3}$$

where:

- $g(t)$ – trending component,
- $s(t)$ – seasonal component,
- $h(t)$ – effects of specific events,
- ε_t – error term (white noise).

The result will consist of graphical outputs illustrating the development of unemployment in the Czech Republic over the next two years, including models that take seasonality into account.

The final part of the research will focus on the relationship between unemployment and the number of job vacancies, which will be illustrated using the Beveridge curve. This relationship will be further statistically verified using Pearson's correlation coefficient, which expresses the strength of the linear relationship between variables. The formula for calculating the correlation coefficient is as follows (MUNI, 2025):

$$r = \frac{\sum_{i=1}^{n}(x_i - x)(y_i - y)}{\sum_{i=1}^{n}(x_i - x)^2 \sum_{i=1}^{n}(y_i - y)^2} = \frac{\sum_{i=1}^{n} x_1 y_1 - nxy}{(n-1)s_x s_y} \tag{4}$$

where:

- r – Pearson's correlation coefficient,
- x_i, y_i – individual values of the observed variables,
- x_1, y_1 – sample means of the variables,
- s_x, s_y – sample standard deviations of the variables,

- n – number of observations.

The hypotheses for testing the relationship will be formulated as follows:

H_0: There is no statistically significant relationship between the unemployment rate and the number of job vacancies.

H_1: There is a statistically significant relationship between the unemployment rate and the number of job vacancies.

The output will include a graphical representation of the Beveridge curve and the results of the correlation analysis, including an interpretation of the direction and strength of the relationship between the variables.

It is expected that the research will show how the Czech Republic performs in comparison with neighbouring countries and that the Prophet model will illustrate whether the unemployment rate will continue to decline in the future or begin to rise. The Beveridge curve should reveal the level of efficiency in matching job vacancies with job seekers in the labour market, which will subsequently be confirmed by the correlation analysis.

Results

The description of basic descriptive statistics for the observed period provides an overview of the main characteristics of unemployment rates across selected countries and the EU (see Table 1).

The calculated averages show that the unemployment rate is highest in Slovakia (9.55%) and in the European Union average (8.39%), while the lowest average values are observed in the Czech Republic (4.39%) and Germany (4.69%).

Variance and standard deviation (indicators of data variability) are by far the highest in Poland and Slovakia, indicating that unemployment rates in these countries fluctuated the most over time. The lowest level of variability is observed in Austria.

The minimum unemployment rate is lowest in the Czech Republic (1.80%) and Germany (2.80%), while the highest maximum values are recorded in Slovakia (15.30%).

Table 1: Descriptive Statistics – Unemployment across Selected Countries

Descriptive statistics	Evropean Union	Czech Republic	Germany	Austria	Poland	Slovakia
Mean	8.39	4.39	4.69	5.46	6.35	9.55
Median	7.90	4.10	4.10	5.40	6.30	9.30
Mode	7.2	2.6	3.2	5.4	3	5.6
Standard deviation	1.88234841	1.93229322	1.6893674	0.81017122	3.0274223	3.3355014
Variance	3.54323556	3.73375712	2.85396234	0.65637740	9.16528582	11.1255702
Minimum	5.70	1.80	2.80	3.70	2.50	5.10
Maximum	12.30	8.40	9.60	8.40	11.90	15.30
Number	223	223	223	223	223	223

Source: Own.

Time series analysis further shows how the unemployment rate has developed over time, specifically through the average annual growth rate and the average relative monthly increment (see Table 2).

The results indicate that all countries exhibit a negative average annual growth rate, with the fastest annual decline recorded in Poland, with an average annual growth rate of -7.1466%.

In terms of the average relative monthly increment, most countries also show negative values. The largest monthly decline in percentage points was again recorded in Poland (-0.514462%) and Germany (-0.212873%). Austria (+0.433811%) and the Czech Republic (+0.008405%) differ in this indicator by showing positive increments, indicating that the unemployment rate in these two countries slightly increased on average each month in absolute terms.

Table 2: Time Series Analysis – Unemployment across Selected Countries

State	Average annual growth rate	Average relative monthly change
EU	-1.9733 %	-0.130833 %
CR	-4.0890 %	0.008405 %
Germany	-4.5688 %	-0.212873 %
Austria	-0.4928 %	0.433811 %
Poland	-7.1466 %	-0.514462 %
Slovakia	-4.1113 %	-0.320880 %

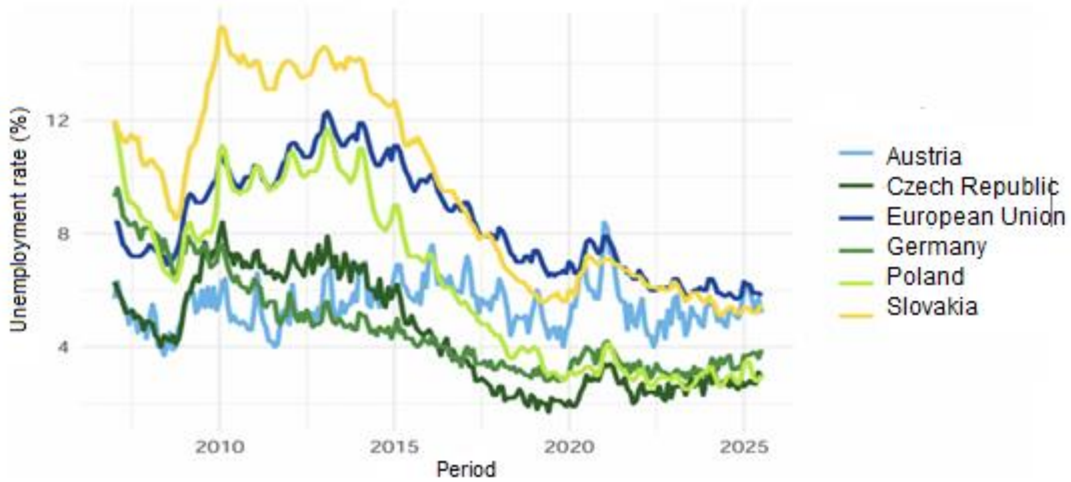
Source: Own.

Graph 1 illustrates the course of unemployment, with the horizontal axis representing the time period (X-axis) and the vertical axis showing the unemployment rate in percentages (Y-axis) (see Graph 1).

The curves reveal a significant downward trend in unemployment for most countries throughout the observed period, following a peak reached approximately between 2012 and 2014. Slovakia (yellow line) consistently recorded the highest absolute unemployment values, while the European Union follows a similar trajectory with slightly lower levels.

In contrast, Germany and the Czech Republic have long exhibited the lowest and most stable unemployment rates. The stabilization at the lowest levels after 2020 indicates that the unemployment rate in the Czech Republic remained below that of Germany for the rest of the observed period.

Graph 1: Unemployment across Selected Countries



Source: Own.

The description of basic descriptive statistics focused solely on the Czech Republic (see Table 3) provides a detailed insight into labour market characteristics over the observed period from January 1993 to July 2025.

The average unemployment rate is 5.36%, while the median reaches 5.08%. The mode, i.e., the most frequently occurring value, is relatively low (2.7%). The values of the standard deviation (2.1823923) and variance (4.762836) indicate moderate volatility of the unemployment rate over time.

Extreme values show that unemployment in the Czech Republic ranged from a minimum of 1.82% to a maximum of 9.33%.

Table 3: Descriptive Statistics – Unemployment in the Czech Republic

Descriptive statistics	Czech Republic
Mean	5.36
Median	5.08
Mode	2.7
Standard deviation	2.1823923
Variance	4.762836
Minimum	1.82
Maximum	9.33
Number	391

Source: Own.

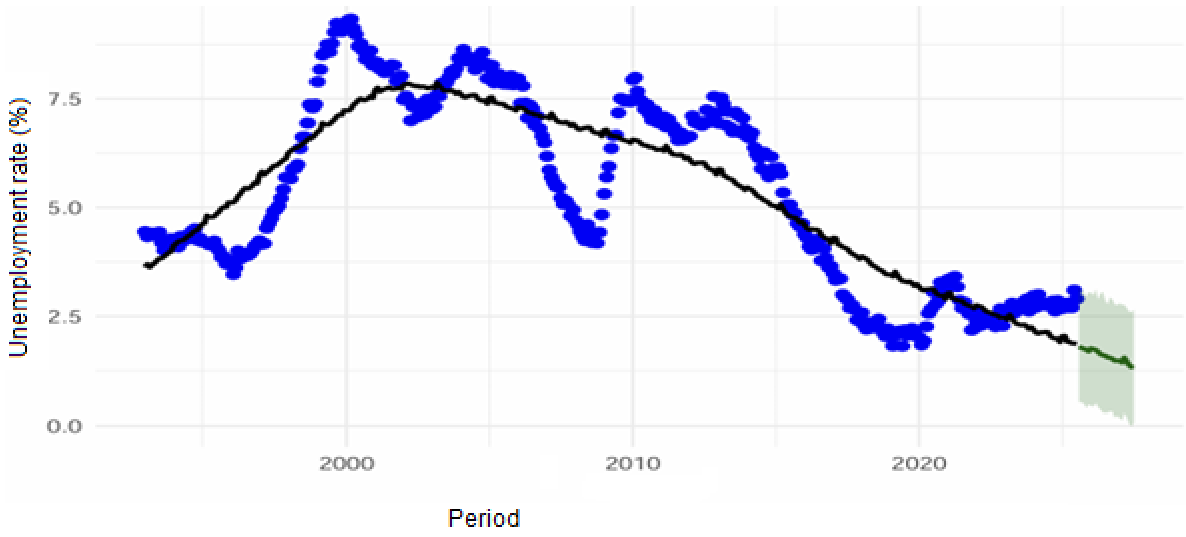
Graph 2 illustrates the development of the unemployment rate in the Czech Republic, capturing actual unemployment values in percentages (blue points) on the Y-axis and the time period from January 1993 to 2025 on the X-axis.

The trend curve (black line) smooths short-term fluctuations and represents the long-term development of unemployment, while the green-highlighted section depicts the forecast of future development.

The graph clearly shows the cyclical nature of unemployment: after an increase at the turn of the millennium, a decline follows, peaking around 2008, then a renewed increase during the economic crisis, and subsequently a gradual decrease until the period before 2020.

The forecasted part of the graph (green segment) indicates a slight further decline in unemployment and its stabilization below the 2.5% threshold, while the confidence interval reflects the possible variability of future development.

Graph 2: Prophet – Unemployment Development in the Czech Republic with Forecast



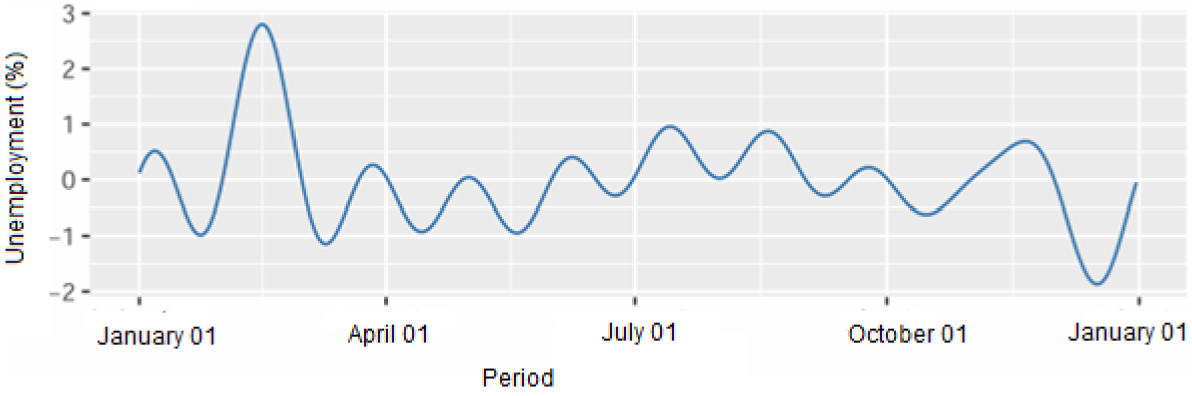
Source: Own.

Graph 3 illustrates the seasonality of unemployment, revealing regular fluctuations that repeat within a calendar year.

The horizontal axis (period) represents the months, while the vertical axis (Y) shows the value of the seasonal component in percentages. The curve clearly indicates a strong and consistent seasonal pattern.

The unemployment rate in the Czech Republic exhibits seasonal peaks during the winter months, which subsequently decline throughout the spring. Seasonal lows regularly occur during the summer months and towards the end of the year. The seasonal maximum reaches approximately 3 percentage points.

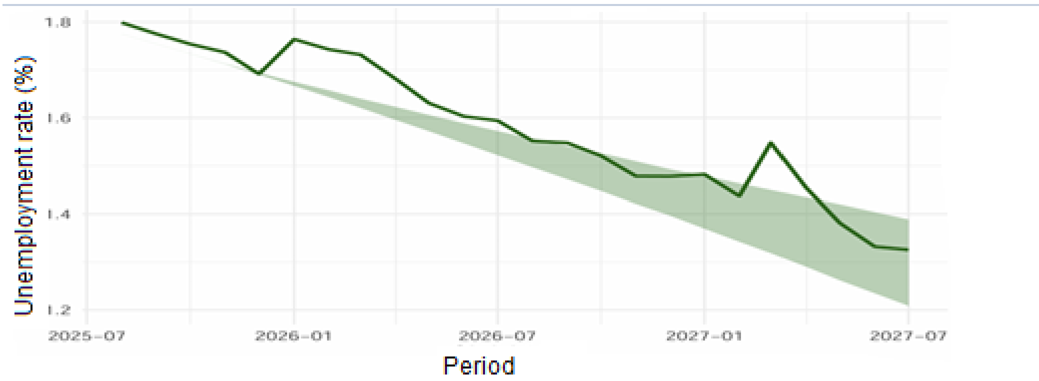
Graph 3: Prophet – Seasonality – Unemployment in the Czech Republic



Source: Own.

The graphical representation of the unemployment forecast in the Czech Republic from August 2025 to July 2027 shows the time development of the expected unemployment rate (Y-axis in %) over the given period (X-axis) (see Graph 4). The expected trajectory (the central solid curve) exhibits a slightly decreasing trend, which corresponds to the numerical values presented in Table 4. The shaded area beneath the curve represents the confidence interval of the forecast, which widens over time. This indicates that as the prediction horizon increases, the uncertainty regarding the actual future value of the unemployment rate also grows.

Graph 4: Prophet – Forecast of Unemployment in the Czech Republic for the Next Two Years



Source: Own.

The table of unemployment forecasts for the Czech Republic provides estimated values of unemployment for future periods, including confidence intervals (see Table 4). For each date, a central value is given, representing the most probable estimate of the unemployment rate. In addition, the lower interval and upper interval are presented, which define the range within which the actual unemployment rate is expected to fall with a given level of probability.

Table 4: Prophet – Forecast of Unemployment in the Czech Republic for the Next Two Years

Date	Point estimate	Lower interval	Upper interval
01.08.2025	1.844731	0.57020256	3.146939
01.09.2025	1.821956	0.46216776	3.184236
01.10.2025	1.801319	0.49461464	3.147863
01.11.2025	1.783815	0.40285635	3.198934
01.12.2025	1.738479	0.37397671	3.064389
01.01.2026	1.808563	0.49563190	3.183240
01.02.2026	1.786518	0.36059691	3.030000
01.03.2026	1.775676	0.40779473	2.975391
01.04.2026	1.726995	0.52294954	2.952433
01.05.2026	1.677172	0.29257524	3.107239
01.06.2026	1.651483	0.26933520	2.962352
01.07.2026	1.643374	0.25501295	2.958124
01.08.2026	1.603712	0.32994160	2.908947
01.09.2026	1.600042	0.29091068	2.904627
01.10.2026	1.572019	0.31459518	2.961944
01.11.2026	1.528732	0.19014071	2.931600
01.12.2026	1.527005	0.21724788	2.833219
01.01.2027	1.535013	0.21328662	2.905693
01.02.2027	1.489389	0.22857990	2.803079
01.03.2027	1.593299	0.23956068	2.878602
01.04.2027	1.502820	0.23362862	2.829042
01.05.2027	1.432253	0.09968618	2.814934
01.06.2027	1.386293	0.03559164	2.770452
01.07.2027	1.358400	0.08200515	2.634796

Source: Own.

The subsequent descriptive statistics for the Czech Republic are extended by a comparison of the number of unemployed persons and the number of job vacancies (see Table 5). The average values indicate that the mean number of unemployed persons is 414.61 thousand, while the average number of job vacancies is 137.13 thousand.

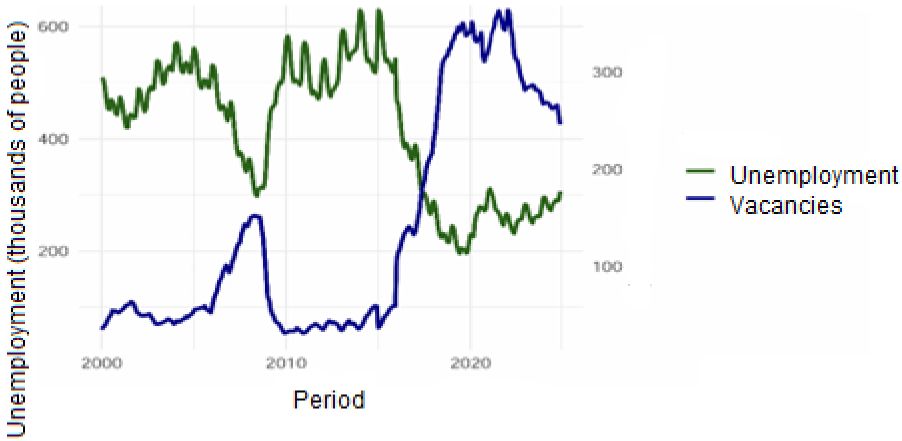
Table 5: Descriptive Statistics – Unemployment and Job Vacancies in the Czech Republic

Descriptive statistics	Unemployed	Number of job vacancies
Mean	414.61	137.13
Median	454.24	59.90
Mode	629.274	54.2
Standard deviation	120.3429148	116.329343
Variance	14482.41714	13532.51604
Minimum	195.72	30.80
Maximum	629.27	363.92
Number	300	300

Source: Own.

The graphical representation of the development of unemployment and job vacancies in the Czech Republic shows the progression of both indicators over time (period, X-axis), with each variable measured on its own vertical axis (Y-axis for unemployment in thousands of persons and Y-axis for vacancies in thousands of positions) (see Graph 5). The trends reveal a strong negative correlation between the two time series: when unemployment (green curve) decreases, job vacancies (blue curve) increase, and vice versa. This relationship is particularly evident after 2010, when a significant decline in unemployment was accompanied by a sharp rise in the number of vacancies. Unemployment reached its minimum around 2020, while job vacancies peaked at the same time.

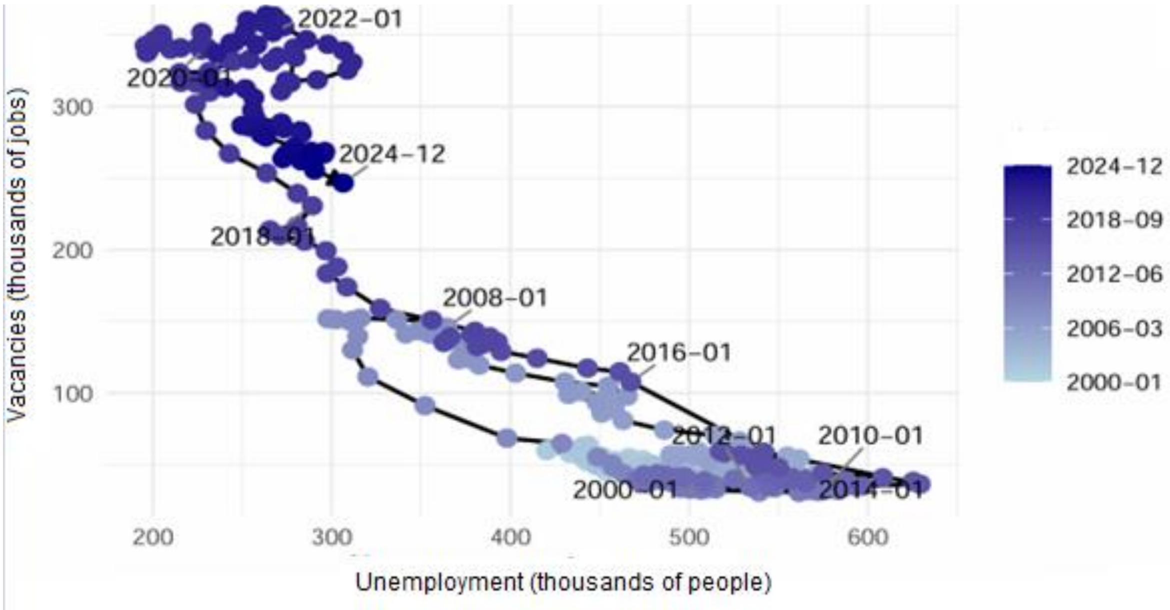
Graph 5: Development of Unemployment and Job Vacancies in the Czech Republic



Source: Own.

The Beveridge curve represents the relationship between the unemployment rate (X-axis) and the number of job vacancies (Y-axis) and is used to assess the efficiency of the labor market over time (see Graph 6). The graph shows movement along the curve over time: during the recession period (approximately 2008–2010), the points shift downwards to the right (high unemployment, low vacancies). Subsequently, the labor market transitions into a phase (approximately after 2016) where the points move upwards to the left (low unemployment, high vacancies).

Graph 6: Beveridge Curve



Source: Own.

The negative relationship between the unemployment rate and the number of job vacancies, which is evident from Graph 5 and Graph 6, is also statistically confirmed. To test this relationship, the following hypotheses were established:

H0: There is no statistically significant relationship between the unemployment rate and the number of job vacancies.

H1: There is a statistically significant relationship between the unemployment rate and the number of job vacancies.

The calculated Pearson correlation coefficient reaches a value of –0.930272261, indicating a very strong inverse (negative) relationship between the two variables. Since the coefficient is close to -1, the null hypothesis (H0) is rejected and the alternative hypothesis (H1) is confirmed. This means that as the number of job vacancies increases, the unemployment rate decreases significantly and systematically, and vice versa.

Discussion

Based on the obtained results, it is now possible to answer all three research questions that were defined at the beginning of this study.

RQ1: What was the development of the unemployment rate in the Czech Republic compared to neighboring countries (Germany, Poland, Austria, and Slovakia) since January 2007?

The development of the unemployment rate in the Czech Republic compared with Germany, Austria, Poland, and Slovakia shows that the Czech Republic has long been among the countries with the lowest unemployment rates in the region. This can be attributed to consistently stable labor demand, a relatively low level of structural unemployment, and a strong industrial orientation that has maintained employment even during periods of weaker economic growth.

The results indicate that unemployment in the Czech Republic reached its highest levels around the year 2000 and during the global financial crisis, but a significant and stable decline has been evident since 2014. This trend contrasts particularly with Poland and Slovakia, which exhibit not only higher unemployment rates but also much more pronounced cyclical fluctuations. This may suggest a higher sensitivity of their labor markets to economic shocks, lower matching efficiency, or more significant structural issues in certain regions.

Austria and Germany have long maintained slightly higher unemployment levels than the Czech Republic; however, their development is more stable compared to Poland and Slovakia. The greatest similarity in development can be observed between the Czech Republic and Germany, suggesting that both countries share similar economic conditions, closely interconnected production chains, and highly integrated labor markets.

The average annual growth rate of unemployment is negative for most countries, confirming a long-term decline in unemployment across the region. The Czech Republic shows one of the lowest levels of average relative monthly fluctuation, indicating a more stable environment and greater resilience to cyclical fluctuations. These findings are consistent with Hedvicakova & Pozdilkova (2023), who also identify the Czech Republic as one of the most stable labor markets within the EU.

RQ2: What was the development of the unemployment rate in the Czech Republic since January 1993, and what will be its trend over the next two years?

From January 1993 to July 2025, the unemployment rate in the Czech Republic shows considerable variability shaped by both long-term economic trends and recurring cycles. The first half of the observed period was characterized by high unemployment levels associated with economic transformation and industrial restructuring. Around the turn of the millennium, unemployment reached one of its peak periods, followed by a gradual decline. Another increase was observed during the global financial crisis (2008–2010), and a slight rise also occurred during the COVID-19 pandemic.

An important aspect of this development is the seasonal nature of unemployment in the Czech Republic, reflecting the ongoing influence of sector-specific labor demand (e.g., construction, tourism). This seasonal pattern remains stable over time and confirms the consistent structure of the labor market. Typically, unemployment increases in winter and declines during the summer months.

The Prophet model captured both the overall trend and seasonal fluctuations, enabling the estimation of future values over a two-year horizon (from August 2025 to July 2027). The forecast indicates a slightly decreasing trend, with most values remaining below 2.00%. As the time horizon extends, the confidence interval widens, reflecting increasing uncertainty due to potential economic shocks or changes in labor demand. The result is therefore favorable but should be interpreted as the most likely scenario under stable conditions without extraordinary events.

Similar findings were reported by Bilkova (2023), who also observed increases in unemployment following the monetary crisis in the late 1990s and during the economic recession in the early 2010s.

RQ3: What is the relationship between unemployment and job vacancies in the Czech Republic since January 2000?

The development of unemployment and job vacancies in the Czech Republic since 2000 shows a strong inverse relationship between these two indicators. As the number of job vacancies increases, the unemployment rate consistently decreases, and vice versa. This relationship is typical for labor markets with relatively efficient matching processes, where firms' demand directly influences job seekers' ability to find employment.

The Beveridge curve representation confirms this relationship—the curve takes the form of a clearly downward-sloping function, corresponding to high elasticity between the two variables.

Correlation analysis further supports this finding: the Pearson coefficient of –0.93 indicates a very strong negative relationship. This means that changes in both indicators are strongly interconnected and respond almost immediately to economic cycles. Similar conclusions were reached by Kantova et al. (2018), who demonstrated that the Czech labor market exhibited higher matching efficiency compared to, for example, Sweden.

Overall, the results confirm that the Czech labor market is characterized by rapid adjustment to labor demand in the long run. At the same time, they may point to persistent structural issues, particularly labor shortages in technical fields and regional imbalances.

Conclusion

The aim of this study was to evaluate the development of unemployment in the Czech Republic, compare it with neighboring countries, and subsequently predict its future development. This objective was achieved through quantitative methods, particularly through the use of time series analysis, dynamic indicators, the Prophet forecasting model, and the construction of the Beveridge curve complemented by correlation analysis.

The results showed that the Czech Republic has long maintained one of the lowest unemployment rates in the region, despite significant fluctuations caused by economic crises, the pandemic, and energy-related pressures. Compared to Germany, Austria, Poland, and Slovakia, unemployment in the Czech Republic developed relatively steadily, with the greatest similarity observed with Germany. At the same time, it was found that the long-term development since 1993 exhibits clear cyclical patterns, and the forecast created using the Prophet model suggests that the unemployment rate is likely to decline over the next two years. The analysis of the relationship between unemployment and job vacancies revealed a strong negative relationship, confirmed both by the graphical representation of the Beveridge curve and by the Pearson correlation coefficient (-0.93).

This result indicates that the Czech labor market is characterized by a relatively efficient matching process between employees and job positions, although its efficiency is sensitive to economic cycles.

The obtained data can be used by public administration authorities in planning employment policies, by employers in estimating the future availability of labor, and by analytical institutions evaluating economic development. The contribution of this study lies in providing a comprehensive view of unemployment in the Czech Republic over a long time horizon, combining comparison, forecasting, and structural analysis.

The limitations of the study primarily include its reliance on secondary data, which may have been influenced by the data collection methods of individual institutions. Furthermore, the forecast depends on the assumptions of the Prophet model, which may not capture unexpected shocks or sudden changes in the labor market. The study also did not focus on differences between individual sectors of the economy, which could further enhance the understanding of specific unemployment trends.

Despite these limitations, it can be concluded that the objective of the study was fully achieved. The study provides clear and evidence-based insights into the development of unemployment in the Czech Republic, its future trajectory, and the functioning of the labor market in the context of the relationship between unemployment and job vacancies. It thus offers relevant findings applicable for further academic research as well as practical decision-making.

References

Ahmad, M., Khan, Y. A., Jiang, C., Kazmi, S. J. H., & Abbas, S. Z. (2023). The Impact of COVID-19 on Unemployment Rate: An Intelligent Based Unemployment Rate Prediction in Selected Countries of Europe. *International Journal of Finance & Economics, 28*(1), 528–543. https://doi.org/10.1002/ijfe.2434

Albertini, M., & Piccitto, G. (2023). Linked Generations: Child's Transition Into Unemployment and Parents' Mental Well-Being. *European Sociological Review, 39*(4), 501–515. https://doi.org/10.1093/esr/jcac053

Babangida, J. S., Khan, A. U. I., & Aysan, A. F. (2024). Examining the Shifting Dynamics of the Beveridge Curve in the Turkish Labor Market during Crises. *Economies, 12*(5), 110. https://doi.org/10.3390/economies12050110

Bilkova, D. (2023). The Czech Republic's Economy since the 1990s and its Development Forecasts: Selected Macroeconomic Indicators. *Inzinerine Ekonomika-Engineering Economics, 34*(4), 370–383. https://doi.org/10.5755/j01.ee.34.4.27427

Cardona-Arenas, C. D. (2025). Exploring Unemployment Persistence: A Probabilistic Analysis in 20 OECD Countries to Understand its Social Implications. *International Journal of Sociology and Social Policy, 45*(1/2), 86–105. https://doi.org/10.1108/IJSSP-06-2024-0245

Český statistický úřad [Czech Statistical Office]. (2025). Míry Zaměstnanosti, Nezaměstnanosti a Ekonomické Aktivity - Říjen 2025 [Employment, Unemployment and Economic Activity Rates - October 2025]. ČSÚ [CZSO]. https://csu.gov.cz/rychle-informace/miry-zamestnanosti-nezamestnanosti-a-ekonomicke-aktivity-rijen-2025Eurostat. (2025). Unemployment Rate (%) - Monthly Data. *Eurostat*. https://ec.europa.eu/eurostat/databrowser/view/ei_lmhr_m__custom_18232778/default/table

Flek, V., Hala, M., & Mysikova, M. (2022). The Ins and Outs of Central European Unemployment. *Baltic Journal of Economics, 22*(1), 49–67. https://doi.org/10.1080/1406099X.2022.2083306

Hančlová, J., & Tvrdý, L. (2003). Úvod do Analýzy Časových Řad [Introduction to Time Series Analysis]. VŠB-TU Ostrava [VSB – Technical University of Ostrava]. https://intranet.fd.cvut.cz/department/k611/PEDAGOG/VSM/7_AnalyzaCasRad.pdf

Hedvicakova, M., & Pozdilkova, A. (2023). Analysis of Key Macroeconomic Indicators and Their Relationship to Unemployment in the Czech Republic. *Proceedings of the 16th International Conference Liberec Economic Forum 2023*, 416–424. https://doi.org/10.15240/tul/009/lef-2023-45

Huruta, A. D. (2024). Predicting the Unemployment Rate Using Autoregressive Integrated Moving Average. *Cogent Business & Management, 11*(1), 2293305. https://doi.org/10.1080/23311975.2023.2293305

Jamaludin, S., Huay, C. S., Safian, S. S., & Aziz, M. R. A. (2025). Revisiting the Beveridge Curve: Evidence from the Malaysia Labour Market. *Environment-Behaviour Proceedings Journal, 10*, 195–203. https://doi.org/10.21834/e-bpj.v10iSI28.6969

Jo, C., Kim, D. H., & Lee, J. W. (2023). Forecasting Unemployment and Employment: A System Dynamics Approach. *Technological Forecasting and Social Change, 194*, 122715. https://doi.org/10.1016/j.techfore.2023.122715

Jumambayev, S., Halicka, K., Dzhulaeva, A., Ilyashova, G., & Dosmbek, A. (2025). Multivariate Time Series Models of Development for Countries with Transitional Economies and Prospects for Post-COVID Growth. *E & M Ekonomie a Management, 28*(2), 1–24. https://doi.org/10.15240/tul/001/2025-2-001

Kantova, M., Prudka, S., Arltova, M., & Kotynkova, M. (2018). Efficiency of Labour Market Policy Changes in the Czech Republic and Sweden in 2006-2015. *Politicka Ekonomie, 66*(4), 411–429. https://doi.org/10.18267/j.polek.1222

Korecko, J., & Vravec, J. (2023). Long-Term Unemployment as a Risk Factor for the Sustainability of Business Development in Slovakia and the European Union. *Economics, Management & Business 2023: Contemporary Issues, Insights and New Challenges*, 18–27.

Krkoskova, R. (2019). Analysis of Labour Market Development in the Czech Republic. *37th International Conference on Mathematical Methods in Economics 2019*, 314–319.

Malisauskaite, G., Nizalova, O., & Xanthopoulou, D. (2022). Unemployment and Well-Being of Europeans Across the Life Cycle: The Role of Countries' Macroeconomic Situation. *Social Indicators Research, 162*(3), 1387–1412. https://doi.org/10.1007/s11205-022-02892-y

Matousova, D. (2021). Analysis of the Share of Unemployed Persons in Five Czech Regions with the Focus on the Impacts of the Covid-19 Pandemic on the Labour Market. *Proceedings of the International Scientific Conference Economic and Social Policy*, 288–300.

Ministerstvo práce a sociálních věcí [Ministry of Labour and Social Affairs]. (2025). Nezaměstnanost – Měsíční [Unemployment – Monthly]. MPSV [MoLSA]. https://www.mpsv.cz/nezamestnanost-mesicni

Molnar, T., Daniel, Z. A., Barna, K. M., & Kozma, D. E. (2024). Trends in the Czech and Hungarian Labour Markets from a Regional Perspective, Especially in Light of the Two Recent Crises. *Regional Statistics, 14*(3), 566–588. https://doi.org/10.15196/RS140307

Moridian, A., Radulescu, M., Kumar, P., Radu, M. T., & Mohammad, J. (2024). New Insights on Immigration, Fiscal Policy and Unemployment Rate in EU Countries—A Quantile Regression Approach. *Heliyon, 10*(13), e33519. https://doi.org/10.1016/j.heliyon.2024.e33519

MUNI [Masaryk University]. (2025). Základy Korelační Analýzy [Basics of Correlation Analysis]. Masarykova Univerzita [Masaryk University]. https://is.muni.cz/www/98951/41610771/43823411/43823458/44159634/44707073/Pavlik_-Biostatistika-_kapitola_11.pdf

Nguyen, V. B. (2022). Counter-Cyclical Fiscal Policy in Developed Countries: Does Governance Hinder. *Prague Economic Papers, 31*(6), 482–508. https://doi.org/10.18267/j.pep.814

Otexts. (2025). Prophet Model. *Otexts*. https://otexts.com/fpp3/prophet.html

Pham, V. H., Vu, N. H., Nguyen, V. S., & Dinh, V. T. (2023). Macro Factors Affecting Unemployment and Application for Labor Laws of Vietnam. *Journal of Law and Political Sciences, 38*(3), 33–55.

Poor, J., Slavic, A., Nikolic, M., & Berber, N. (2021). The Managerial Implications of the Labor Market and Workplace Shortage in Central Eastern Europe. *Strategic Management, 26*(2), 31–41. https://doi.org/10.5937/StraMan2102031P

Rafei, E., Shabani, Z. D., & Hadian, E. (2023). Driving Factors on Unemployment in Iran's Provinces: Do Temporal and Spatial Dynamics Matter? *Regional Science Policy and Practice*. https://doi.org/10.1111/rsp3.12715

Sanchez, P. F., Garcia-Centeno, M. C., Ocana, I. H., & Fernandez, M. J. A. (2023). Unemployment in Greece and Cyprus in the 21st Century: An Analysis From a European Perspective. *Revista De Economia Mundial, 64*, 129–150. https://doi.org/10.33776/rem.vi64.7511

Simionescu, M., & Cifuentes-Faura, J. (2022). Can Unemployment Forecasts Based on Google Trends Help Government Design Better Policies? An Investigation Based on Spain and Portugal. *Journal of Policy Modeling, 44*(1), 1–21. https://doi.org/10.1016/j.jpolmod.2021.09.011

Van Hooft, E. A. J., Kammeyer-Mueller, J. D., Wanberg, C. R., Kanfer, R., & Basbug, G. (2021). Job Search and Employment Success: A Quantitative Review and Future Research Agenda. *Journal of Applied Psychology, 106*(5), 674–713. https://doi.org/10.1037/apl0000675

Wani, H. R., & Ahmed, A. (2024). A Study Exploring the Impact of Unemployment on the Psychological Well-Being of Youth. *Asian Social Work and Policy Review, 18*(2), e12316. https://doi.org/10.1111/aswp.12316

Zielinski, M. (2022). The Effect of the COVID-19 Pandemic on the Labor Markets of the Visegrad Countries. *Sustainability, 14*(12), 7386. https://doi.org/10.3390/su14127386

Contact address of the authors:

Kateřina Jíchová, Institute of Technology and Business in České Budějovice, School of Expertness and Valuation, Okružní 5170/10, 37001 České Budějovice, Czech Republic, e-mail: jichova@mail.vstecb.cz

Ing. Jozef Adamko, PhD., MBA, Institute of Technology and Business in Prešov, Faculty of Economics, Management and Marketing, Masarykova 22, 080 01 Prešov, Slovak Republik, e-mail: jozef.adamko@centrum.sk

Development and Forecast of Unemployment in the Czech Republic

Tereza Kalinová[1], Vilém Kovač[2]

[1,2] Institute of Technology and Business in České Budějovice, School of Expertness and Valuation

Abstract

Unemployment is one of the key indicators of the state of the economy and labor market stability, and its development is sensitive to economic cycles and extraordinary economic shocks. The aim of this study was to evaluate the development of unemployment in the Czech Republic over the last ten years, identify the key factors influencing its dynamics, and propose a predictive model for estimating future developments. To achieve this goal, time series analysis, multivariate regression analysis, and the ARIMA seasonal model were used. The results showed significant seasonality in unemployment and its decline to historically low levels in 2017–2019. The impact of the COVID-19 pandemic was only a temporary disruption of the long-term trend, followed by a stabilization of the unemployment rate. The number of registered job seekers and the number of job vacancies had a significant impact on the development of unemployment. The prediction indicated a slight increase in the unemployment rate in 2026 without any indication of a significant structural break. The paper provides a comprehensive view of unemployment trends and, with the proposed model, offers a tool for further research and decision-making in the labor market. However, the scope of available data is a limitation.

Keywords: Unemployment, time series, regression model, ARIMA model, labour market, forecasting, economic trends.

Introduction

Unemployment represents one of the most important macroeconomic indicators, as it directly affects economic growth, inflation, household consumption, and the stability of public finances. In economic theory, unemployment is understood as an inevitable phenomenon that occurs even under full employment, where the so-called natural rate of unemployment corresponds to stable inflation (Froncková et al., 2019). Therefore, the unemployment rate is a key indicator for economic policy-making and a tool for assessing labor market efficiency.

In recent years, the dynamics of unemployment in the Czech Republic have changed significantly due to the interplay of several external and internal factors. The COVID-19 pandemic led to a temporary collapse of the labor market, business closures, and job losses, disrupting standard employment mechanisms (Kapicka & Rupert, 2022). At the same time, the crisis highlighted the importance of frictional and structural factors affecting re-entry into the labor market. Current research shows that the pandemic had a disproportionate impact on young workers and women, with these groups facing higher unemployment than others (Fan et al., 2025).

In addition to short-term shocks, long-term structural influences also affect the Czech labor market, including digitalization, automation, and labor migration. The inflow of workers from Ukraine and other countries changes the structure of labor supply and influences the regional distribution of employment. Research confirms that migration, minimum wage levels, and minor changes in capital control and appropriation can significantly affect unemployment levels, with increases in the minimum wage in some cases even reducing unemployment (Pi & Duan, 2023).

Further studies emphasize the importance of information frictions and asymmetries in the labor market, which may lead to inefficient job allocation and greater wage rigidity (Bradley & Mann, 2024). This mechanism helps explain why unemployment may remain high even after an economic crisis ends, while newer models suggest that both workers and firms gradually learn, which better reflects real-world data.

The risk of a significant increase in unemployment is also linked to the credit cycle and developments in financial markets. Kiley (2022) demonstrates that when unemployment is low and credit growth is high, the likelihood of a subsequent sharp increase in unemployment rises, with short- and medium-term risk factors differing. These findings confirm that unemployment forecasting must consider not only economic cycles but also structural and behavioral characteristics of the labor market.

The choice of this topic is driven by a personal interest in the functioning of the labor market and its sensitivity to external shocks and structural changes. Unemployment is not merely a statistical indicator but has profound impacts on social stability, living standards, and economic growth. The topic is both current and socially relevant, as the analysis and forecasting of unemployment provide practically useful insights for policymakers, businesses, and public institutions. This study aims to contribute to a deeper understanding of the factors shaping unemployment development in the Czech Republic and thereby support the creation of more effective economic policies.

The aim of this study is to evaluate the development of unemployment in the Czech Republic over the past ten years, identify the key factors influencing its dynamics, and propose a predictive model for estimating future development.

In relation to this aim, the following research questions are defined:

RQ1: What was the monthly development of unemployment in the Czech Republic in the period 2014–2024, and what main trends can be identified?

This question provides an overview of the historical dynamics of unemployment and helps identify key trends. Understanding the development of unemployment is essential for detecting patterns that influence the labor market and for building a predictive model.

RQ2: Which factors (structural changes, labor migration, pandemic) most significantly influence unemployment dynamics?

Answering this question makes it possible to identify the main determinants of changes in unemployment. Knowledge of these factors is crucial for designing effective economic and social policies and for modeling future development.

RQ3: How can future unemployment development in the Czech Republic be predicted based on available data?

This question provides the practical output of the study—a predictive model that enables estimation of future unemployment dynamics. Its development is essential for planning measures and minimizing negative impacts on the labor market.

Data and methods

This chapter is devoted to the description of the data and methods that will be used in the empirical part of the study. The aim is to present the data sources, the method of data processing, and the analytical approaches that will enable the research questions to be answered and the objective of the study to be fulfilled.

Data

The empirical part of the study will be based on secondary data obtained from official statistical sources, specifically the Czech Statistical Office, the Ministry of Labour and Social Affairs, and the Kurzy.cz portal. These institutions provide long-term reliable and methodologically consistent data on the development of unemployment in the Czech Republic, both at the national and regional levels.

The analyzed data will include the registered unemployment rate, unemployment by gender, age, and educational attainment, as well as the number of job vacancies. The data are collected from secondary sources through content analysis of official statistical databases, specifically those of the Czech Statistical Office and the Ministry of Labour and Social Affairs. In this context, content analysis is used as a systematic procedure for selecting, classifying, and harmonizing relevant statistical indicators in order to create a consistent dataset suitable for subsequent quantitative analysis.

The analysis will focus on the period from January 2014 to December 2024, with monthly data frequency, allowing the development of unemployment to be captured both during periods of economic stability and during crisis years, particularly the COVID-19 pandemic and the economic impacts of the war in Ukraine. The dataset has subsequently been extended with the most recent available monthly data up to October 2025 to ensure the timeliness of the analysis and enable forecasting for 2026.

Before the analysis, the data will undergo consistency and completeness checks. Missing values will be handled through imputation based on the average of neighboring periods, taking seasonal fluctuations into account. Subsequently, potential outliers will be identified and verified using supplementary statistics to ensure data validity. To ensure comparability and eliminate short-term shocks, the time series will be normalized and smoothed using appropriate statistical techniques, such as moving averages.

The basic characteristics of the data will be described using descriptive statistics, specifically the arithmetic mean, median, mode, standard deviation, and coefficient of variation. These indicators will allow readers to understand the central tendency, dispersion, and variability of the observed variables. This step will also ensure that the subsequent regression analysis is based on a well-prepared dataset.

The data will be collected regularly from already published statistical time series and therefore represent secondary data. This approach complies with scientific research standards and ensures transparency and reproducibility of results. Data sources will be properly cited according to relevant standards and are publicly available.

It is expected that data processing will enable the identification of long-term trends in unemployment development, differences between individual regions and socioeconomic groups, and the impacts of extraordinary events such as the COVID-19 pandemic or the economic crisis caused by the war in Ukraine. These findings will provide the basis for quantitative data processing in regression analysis and will enable the research questions of the study to be answered.

Methods

A quantitative approach will be used for data processing, enabling a comprehensive evaluation of unemployment development, identification of its key determinants, and description of both regional and temporal differences. This method provides a broader interpretative framework while allowing the identified relationships to be quantified using statistical models.

In the first phase, a content analysis of secondary data will be conducted, with the aim of systematically describing the main trends in unemployment development during the period 2014-2024. The content analysis will include classification and categorization of observed variables according to gender, age, educational attainment, and regional affiliation. This approach will make it possible to identify structural differences between groups and capture changes caused by macroeconomic shocks, seasonal fluctuations, or extraordinary events affecting the labor market (such as the COVID-19 pandemic or the impacts of the war in Ukraine). The outputs of the content analysis will serve as a basis for formulating assumptions regarding relationships between variables, which will subsequently be tested using quantitative methods.

In the second phase, multivariate regression analysis will be applied. Its aim is to quantify the relationship between the unemployment rate as the dependent variable and selected socioeconomic indicators as independent variables. This approach will make it possible to determine the extent to which selected factors (e.g., the number of job vacancies) contribute to the variability of the unemployment rate and in what direction these factors influence it. The general form of the regression equation will be as follows (Source: Gujarati, 2015):

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n + \varepsilon \tag{1}$$

where:
Y – unemployment rate [%],
$X_1 \dots X_\mathrm{n}$ – independent variables (selected socioeconomic indicators),
β_0 – model constant (intercept)
$\beta_1 \dots \beta_\mathrm{n}$ – regression coefficients expressing the strength and direction of the influence of individual factors,
ε – random component (error term / residual).

Before estimating the model, the basic assumptions of regression analysis will be verified. These include whether the variables exhibit an approximately linear relationship, whether the model errors are homoscedastic and do not show systematic bias, whether the explanatory variables are not excessively correlated with each other, and whether the residuals are approximately evenly distributed over the observed period. Assessing these assumptions is necessary to ensure the validity of the results and the correct interpretation of the estimated coefficients. Statistical significance will be evaluated based on p-values, and the overall quality of the model will be assessed using the coefficient of determination (R^2). Calculations and graphical outputs will be processed using appropriate statistical software.

As a supplementary quantitative method, the ARIMA model will also be used, allowing the analysis of time series dynamics independently of the influence of other variables. This model is suitable for identifying the trend, seasonal, and random components of a time series, and thus for an independent assessment of the temporal structure of the unemployment rate over the observed period. The general form of the ARIMA model is as follows (Source: Box & Jenkins, 2016):

$$\varphi(\mathrm{L})(1-\mathrm{L})^{d}\, Y_\mathrm{t} = \theta(\mathrm{L})\varepsilon_\mathrm{t} \tag{2}$$

where:
$\varphi(L)$ – autoregressive operator,
$\theta(L)$ – moving average operator,
L – lag operator,
d – order of differencing,
ε_t – random component (white noise).

The ARIMA model will be estimated in the Python programming language, specifically using the "statsmodels" and "pmdarima" libraries, which implement the Box–Jenkins methodology, including the automatic identification of optimal model parameters. The estimation will be performed on monthly data for the period 2014-2025, with the subsequent forecast covering the months of 2026.

The ARIMA model will be used primarily to assess trend, seasonality, and short-term volatility, as well as to generate forecasts of future unemployment rate development. The results will serve as a complement to the regression analysis. Both approaches will make it possible to verify whether the identified trends remain consistent under an alternative modeling framework, thereby increasing the reliability of the conclusions.

The methodology will also include time series smoothing, aimed at reducing distortions caused by short-term fluctuations, extraordinary events, and seasonal effects. A moving average will be used for smoothing, contributing to greater comparability and interpretability of the time series.

The research procedure will include data collection and preparation, followed by content analysis and the calculation of basic descriptive statistics, the application of the regression model, and supplementary time series analysis using the ARIMA method. The results will be presented in the form of tables, visualizations, and interpreted forecasts to clearly address all research questions. It is expected that the combination of the selected methods will enable the identification of the main determinants of the unemployment rate, the description of temporal differences, and a comprehensive answer to the defined research questions.

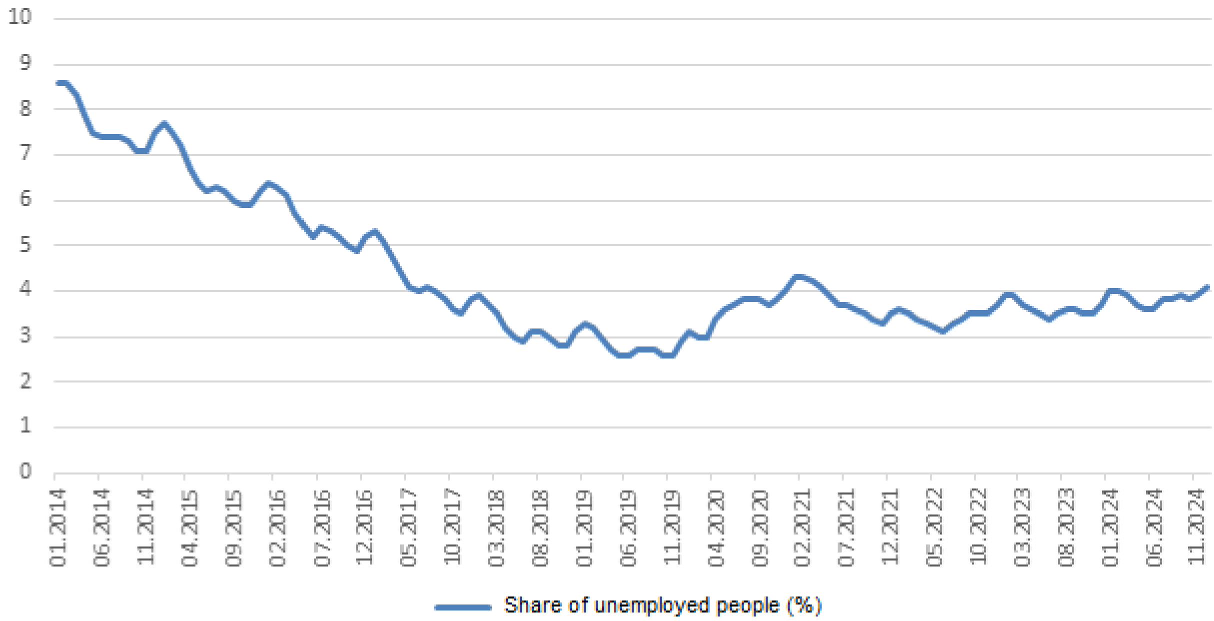
Results

This chapter presents the results of the empirical part of the study obtained based on the procedures described in the Methodology chapter. The results are structured according to the applied analytical approaches and include a description of the development of the unemployment rate in the period 2014-2024, the outputs of the multivariate regression analysis, and a forecast of future development using the ARIMA model. Each section of the chapter contains only the obtained values and statistical outputs, supplemented by graphical and tabular appendices.

Development of the unemployment rate in the period 2014–2024

For the analysis of unemployment development, monthly data for the period from January 2014 to December 2024 were used, totaling 132 observations. The time series of the unemployment rate is illustrated in Graph 1, which captures the development of values over the observed period.

Graph 1: Development of the Unemployment Rate in the Czech Republic (2014-2024)



Source: Own.

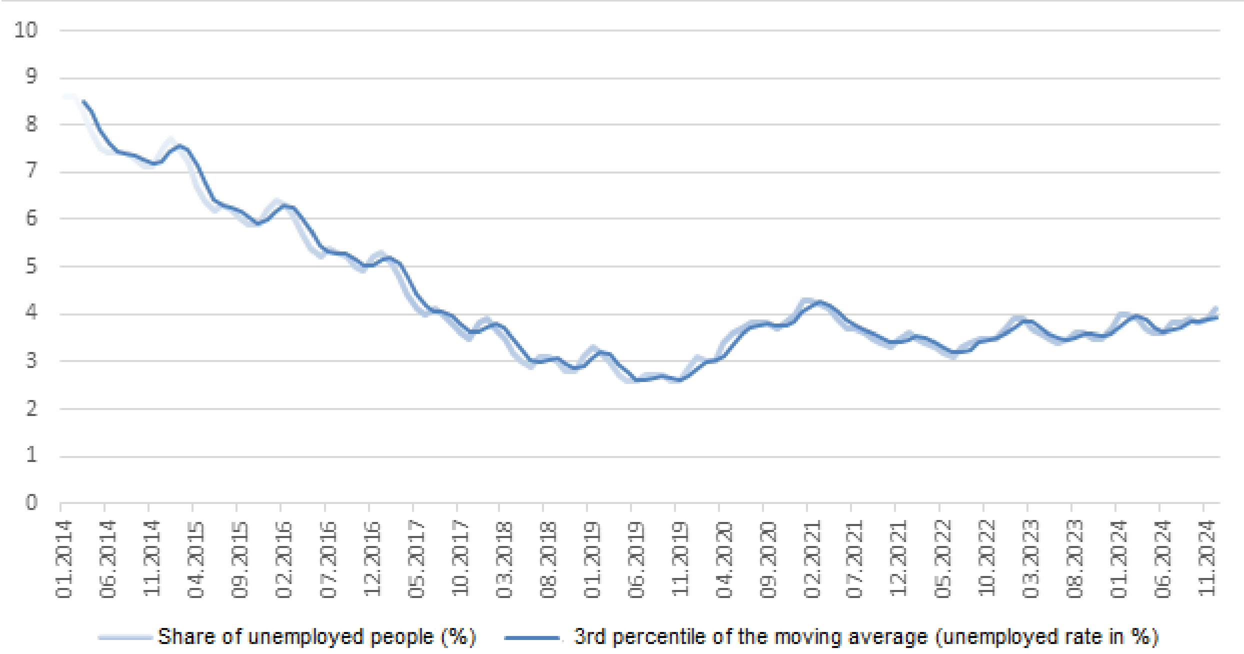
From the time series in Graph 1, it is evident that the unemployment rate in January 2014 was around 8.6%, representing the highest value of the entire observed period. This is followed by a long-term gradual decline, with the unemployment rate stabilizing at approximately 5% by the end of 2016. In 2017, the decline continues to values between 3.5% and 4%, with the lowest value of the entire period recorded in the first half of 2019, when the unemployment rate reached approximately 2.6%.

The time series also exhibits regular seasonality. This recurring pattern is clearly visible in Graph 1. In most years, an increase in the unemployment rate can be observed in January and February, while the lowest values are typically reached during the summer months, particularly in July and August. This seasonal cycle is evident throughout the entire observed period, regardless of the overall level of unemployment.

From a year-by-year perspective, periods of increased volatility can also be identified. In 2020, there is a more pronounced fluctuation, with the unemployment rate rising from approximately 2.9% in January to more than 3.8% in July. In the following months of 2021 and 2022, the unemployment rate mostly ranges between 3.3% and 4%, with fluctuations remaining mild and regular. In 2023, a slight increase is observed, with unemployment generally ranging between 3.5% and 3.9%. The year 2024 concludes the observed period with values around 4%, representing a slight increase compared to the previous year.

To clarify short-term fluctuations, a three-point moving average was applied to the time series. The smoothed curve shown in Graph 2 better illustrates the overall trend and confirms the long-term decline in unemployment until 2019, followed by its stabilization at around 3–4%.

Graph 2: Smoothed Development of the Unemployment Rate



Source: Own.

To complement the presentation of the results, the basic statistical characteristics are presented in Table 1 below.

Table 1: Descriptive characteristics of the unemployment rate, 2014–2024

Share of unemployed persons [%]	
Aritmetmetic mean	4.37
Median	3.8
Mode	3.5
Standard deviation	1.52
Minimum	2.6
Maximum	8.6
Number	132

Source: Own.

Results of the regression analysis

The regression analysis was conducted on a dataset of 132 monthly observations covering the period from January 2014 to December 2024. The dependent variable was the unemployment rate expressed as a percentage. Two labour market variables were included as independent variables: the number of registered job seekers and the number of job vacancies. The estimation was carried out using a multiple linear regression model, with all values processed at the same monthly frequency.

The results of the model are presented in Table 2, which includes the estimated coefficients, their standard errors, t-statistics, and p-values. The table also contains key model characteristics such as the coefficient of determination (R^2), adjusted R^2, the F-test value, and the number of observations included.

Table 2: Results of the multiple regression analysis

	Coefficients	**Standard error**	**t – Statistics**	**Value P**
Limit	1.99802060	1.15812957	1.72521335	0,08688382
Job seekers (UoZ)	0.00008433	0.00001741	4.84385364	0,00000359
Job vacancies (VPM)	-0.00000576	0.00000164	-3.51164903	0,00061431
Model statistics				
R^2	0.8715			
Adjusted R^2	0.8695			
F	437.54			
p	<0.001			
n	132 observations			

Source: Own.

The coefficient of determination (R^2) reached a value of 0.8715. This value indicates how much of the variability of the dependent variable is explained by the selected independent variables. The adjusted coefficient of determination is 0.8695, which is very close to the original R^2 value, confirming that the inclusion of both explanatory variables is appropriate and does not compromise the stability of the model. The F-test of the model reached a value of 437.54, and its p-value is significantly lower than the 0.01 significance level, indicating that the model as a whole is statistically significant.

The results of the regression analysis show that both included variables have a statistically significant effect on the unemployment rate at the 1% significance level. The coefficient for the number of registered job seekers has a positive value of 0.00008433, with a t-statistic of 4.84 and a p-value lower than 0.001. The coefficient for the number of job vacancies has a negative value of -0.00000576, a t-statistic of −3.51, and a p-value also below 0.001. The low values of the standard errors for both variables indicate the stability and reliability of the regression model results.

The constant term of the model reached a value of 1.998; however, its p-value is 0.086, which is higher than the commonly used significance level of 0.05. Therefore, its statistical significance appears lower compared to the two explanatory variables. Nevertheless, it is included in the table as it represents an integral part of the estimated model.

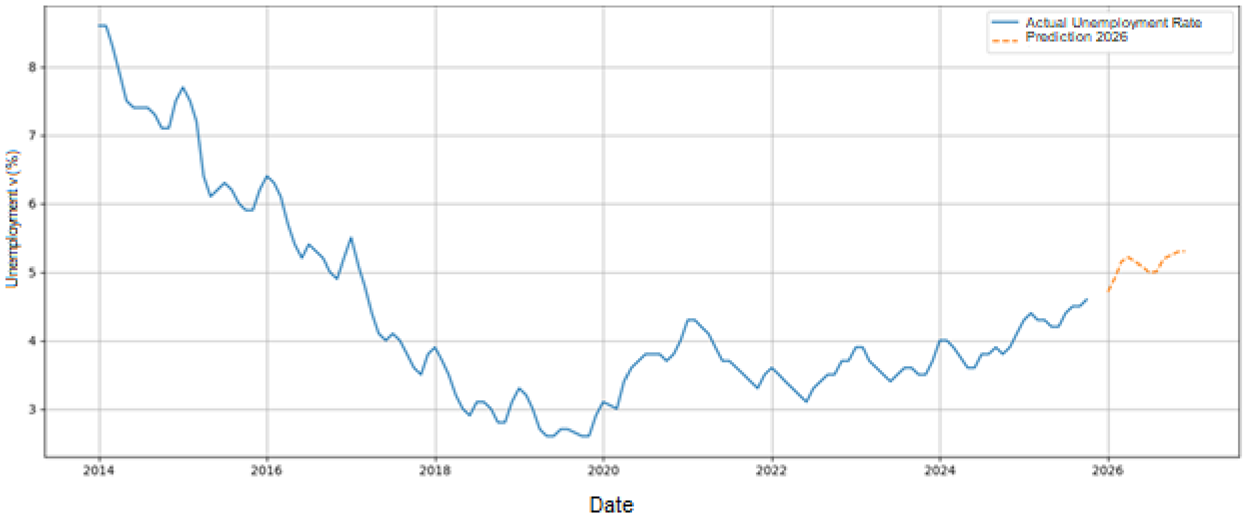
The assumptions of linear regression were verified using basic diagnostic procedures. The residuals are evenly distributed around the zero axis and do not form any systematic patterns. Their variance remains consistent across the range of values, indicating no significant heteroscedasticity. No strong multicollinearity was detected among the explanatory variables. Based on these findings, it can be concluded that the model meets the assumptions required for linear regression.

Forecast of the unemployment rate for 2026

To predict future developments, a time series of monthly unemployment rate values was used, extended with the most recent available data for 2025 (January-October). The forecasting model was constructed using the ARIMA method, estimated in the Python programming environment. The model selection process involved automatic parameter identification based on the AIC information criterion. The result was a seasonal model with a 12-month seasonality, whose parameters enabled the creation of a forecast for the period January-December 2026.

The resulting forecast values are illustrated in Figure 3. The visualization captures both the actual development up to October 2025 and the subsequent projection of values for the entire year 2026.

Figure 3: Development of the unemployment rate in the Czech Republic (2014-2025) + prediction 2026



Source: Own.

The forecasted time series suggests that the model expects a gradual increase in the unemployment rate throughout 2026. The initial value in January is 4.71%, while by the end of the year the predicted values reach approximately 5.30%. Within the year, slight seasonal variability is evident, with lower values estimated for the summer months and higher values for the autumn and winter months. A complete list of the forecasted values is provided in Table 3 in Appendix 1.

Discussion

This chapter interprets the results of the empirical part of the thesis and systematically answers the research questions posed. The findings are interpreted in the context of the literature review and supplemented with key relationships derived from the empirical data. The discussion focuses on the main characteristics of unemployment development, the importance of individual factors, and the suitability of the applied methodology.

RQ1: What was the monthly development of unemployment in the Czech Republic in the period 2014–2024 and what main trends can be identified?

The time series results show several distinct phases in the development of unemployment. At the beginning of the observed period (2014-2016), higher values above 7% are evident, which may be associated with the gradual fading of economic stagnation described by Kapáska (2022). This interpretation is largely consistent with the data; however, the graph also shows that the decline in unemployment was relatively smooth, without significant short-term shocks. This suggests that the Czech labour market was structurally quite resilient at the time, even though literature often emphasizes its sensitivity to economic cycles.

The period 2017-2019 is characterized by a significant decline in unemployment to around 2.6%. This development corresponds with the findings of Pošta (2023) regarding strong labour demand; however, the data indicate that the decline was unusually steep. This may suggest that short-term factors (e.g., labour shortages in industry) played a more significant role than is typically emphasized in the literature. In other words, the actual development may have been more sensitive to specific domestic conditions than general theories about the European labour market suggest.

The pandemic period of 2020 brought fluctuations that are also visible in the data. Unlike some studies (e.g., Zubíková et al., 2023), which expect a more pronounced shock, the time series shows only moderate deviations. This confirms that the impact of the pandemic in the Czech context was weaker than international analyses might suggest. It is possible that government support measures, the specific structure of employment (strong industrial base), and already low unemployment levels before the pandemic mitigated the potential increase.

After 2022, the development stabilizes within the range of 3.5-4%. The stability described in the literature for developed and digitalized labour markets (Priede, 2023) is consistent with this observation. However, the graph also shows that this stability has a strong seasonal component. Regular winter increases and summer decreases occur consistently each year and, in practice, have a stronger influence than long-term structural changes. This seasonality represents the most prominent and reliable pattern in the entire series, as it is more stable than the trend and more pronounced than the impact of the pandemic.

RQ2: Which factors (structural changes, labour migration, pandemic) most influence unemployment dynamics?

The regression analysis confirmed that the most significant determinants of the unemployment rate are two key variables: the number of registered job seekers and the number of job vacancies. Both variables were found to be statistically significant, and their direction aligns with expectations. However, several additional insights emerge that are not always emphasized in the literature.

The positive relationship between the number of job seekers and unemployment is intuitive, but the increase in unemployment is not always linear, suggesting the influence of factors not captured by the model, such as duration of unemployment, structure of job seekers, or seasonal hiring patterns. While literature (e.g., Pošta, 2023) often explains this relationship through regional qualification structures, the data suggest that the dynamics may be more heterogeneous than commonly described.

The negative relationship between job vacancies and unemployment corresponds with findings by Priede (2023); however, the analysis shows that the intensity of this relationship changes over time. During periods of strong economic growth (2017-2019), unemployment decreased significantly even with a smaller increase in vacancies, whereas after 2022 the changes are more moderate. This indicates that the number of vacancies alone may not be sufficient, and their structure, qualification requirements, and regional distribution also play an important role—factors not captured by the model.

Broader influences such as structural changes, digitalization, or technological progress are not directly reflected in the regression. This is mainly due to the lack of suitable monthly indicators. While literature (e.g., Bachmann et al., 2024) often highlights these as key drivers, the analysis suggests they act more as long-term background factors affecting the trend rather than short-term dynamics.

A similar conclusion applies to migration. Although it may theoretically affect labour supply structure, it does not create significant shifts in the time series. This finding aligns with Yılmaz and Günel (2022), although the impact may be even weaker in the Czech context due to relatively low migration levels.

The COVID-19 pandemic appears in the data as a short-term disruption rather than a long-term structural shock. This contrasts with expectations from international studies and may reflect the effect of rapid policy responses, economic structure, and low pre-pandemic unemployment.

RQ3: How can future unemployment developments in the Czech Republic be predicted based on available data?

The forecast was developed using a seasonal ARIMA model, which is generally recommended for monthly economic time series. Parameter optimization based on AIC led to the selection of a model capable of capturing both recurring seasonal patterns and long-term trends.

The results suggest that unemployment may slightly increase in 2026. This is consistent with broader expectations of a slowdown in the European economy (Priede, 2023). The forecast indicates a gradual rise in unemployment, continuing the relative stability observed in 2022-2024.

However, it is important to critically acknowledge that the ARIMA model relies solely on historical values of a single variable and has limited ability to account for sudden shocks or structural changes. If significant events occur in 2026 (e.g., recession, changes in industrial demand, geopolitical developments), the model cannot anticipate them. In this sense, the forecast may appear somewhat “over-smoothed.”

The literature suggests that more advanced hybrid models (e.g., ARIMA-ARNN, ARIMA-SVM; Ahmad et al., 2023) can provide more accurate predictions due to their ability to capture nonlinear patterns. However, their application was beyond the scope of this study due to data and complexity requirements. The use of a seasonal ARIMA model can therefore be considered a reasonable compromise—offering a simple, transparent, and sufficiently reliable forecast given the available data, albeit less flexible than more advanced approaches.

Conclusion

The aim of this thesis was to evaluate the development of unemployment in the Czech Republic over the past ten years, identify the key factors influencing its dynamics, and propose a predictive model to estimate future developments. This objective was achieved through time series analysis, regression modelling, and the ARIMA forecasting model, which together provided a comprehensive view of the functioning of the Czech labour market.

The time series analysis showed that the observed period was not homogeneous in terms of development. In 2014-2016, the data reflected the effects of previous economic stagnation, while the period 2017-2019 was characterized by historically low unemployment around 2.6%. The COVID-19 pandemic caused a temporary disruption of the trend; however, due to stabilisation measures, there was no sharp increase in unemployment. Since 2022, the development has stabilised within the range of 3.5-4%. Throughout the entire period, a strong seasonal pattern is evident, which represents one of the characteristic features of the Czech labour market.

The regression analysis confirmed the importance of two main factors: the number of job seekers and the number of job vacancies. These variables best explain short-term fluctuations in unemployment. Structural or technological changes could not be included in the model due to the lack of data at a monthly frequency, and therefore their influence is only indirectly reflected in long-term trends. The pandemic was confirmed as a short-term shock that only temporarily disrupted the trend.

The predictive part of the thesis used a seasonal ARIMA model, which forecasts a slight increase in unemployment in 2026 and a continuation of stable development without major structural breaks. The model captured both the seasonal pattern and the long-term trend and provided a realistic outlook that can serve as a basis for practical use and further research.

The thesis thus fulfilled its objective by describing the development of unemployment, identifying key factors, and producing a forecast of future trends. A limitation of the research remains the restricted range of explanatory variables, which were not available at the required frequency. Nevertheless, the results form a consistent and methodologically appropriate whole. The contribution of the thesis lies in the integration of multiple analytical approaches and in providing a comprehensive view of the development and expected direction of the Czech labour market.

References

Ahmad, M., Khan, Y. A., Jiang, C. H., Kazmi, S. J. H., & Abbas, S. Z. (2023). The impact of COVID-19 on unemployment rate: An intelligent based unemployment rate prediction in selected countries of Europe. *International Journal of Finance & Economics*, 28(1), 528–543. https://doi.org/10.1002/ijfe.2434

Bachmann, R., et al. (2024). The impact of robots on labour market transitions in Europe. *Structural Change and Economic Dynamics*, 70, 422–441. https://doi.org/10.1016/j.strueco.2024.05.005

Box, G. E. P., Jenkins, G. M., Reinsel, G. C., & Ljung, G. M. (2016). Time *series analysis: Forecasting and control* (5th ed.). Wiley.

Bradley, J., & Mann, L. (2024). A general equilibrium model of the labor market with learning and misallocation. *Journal of Monetary Economics*, 148, 103612. https://doi.org/10.1016/j.jmoneco.2024.103612

Český statistický úřad [Czech Statistical Office]. (n.d.). Míra nezaměstnanosti podle pohlaví a věkových skupin [Unemployment Rate by Sex and Age Groups]. https://vdb.czso.cz/vdbvo2/faces/cs/index.jsf?page=vystup-objekt-parametry&z=T&f=TABULKA&katalog=30853&pvo=ZAMD002

Český statistický úřad [Czech Statistical Office]. (n.d.). Trh práce – základní ukazatele [Labour Market – Basic Indicators]. https://csu.gov.cz/produkty/zam_cr

Český statistický úřad [Czech Statistical Office]. (n.d.). Zaměstnanost a nezaměstnanost – regionální data [Employment and Unemployment – Regional Data]. https://vdb.czso.cz/vdbvo2/faces/cs/index.jsf?page=vystup-objekt&pvo=ZAMD006

Český statistický úřad [Czech Statistical Office]. (n.d.). Veřejná databáze – zaměstnanost a nezaměstnanost [Public Database – Employment and Unemployment]. https://vdb.czso.cz

Eeckhout, J., & Lindenlaub, I. (2019). Search behavior, multiple equilibria, and cyclical outcomes in the labor market. *American Economic Journal: Macroeconomics*, 11(4), 175–234. https://doi.org/10.1257/mac.20180105

Fan, X., Xu, Z., Skare, M., & Wang, X. (2025). The role of entrepreneurship and management in economic systems. *International Entrepreneurship and Management Journal*, 21(1), Article 71. https://doi.org/10.1007/s11365-025-01095-4

Fronckova, K., Prazak, P., & Soukal, I. (2019). Review of Kalman filter employment in the NAIRU estimation. *Systems*, 7(3), 33. https://doi.org/10.3390/systems7030033

Gujarati, D. N., & Porter, D. C. (2015). *Basic econometrics* (6th ed.). McGraw-Hill Education.

Kapas, J. (2022). Has COVID-19 caused a change in the dynamics of the unemployment rate? The case of North America and continental Europe. *Regional Statistics*, 12(1), 3–26. https://doi.org/10.15196/RS120107

Kapicka, M., & Rupert, P. (2022). Labor market dynamics during COVID-19: SIR epidemic model and frictional labor market. *Journal of Economic Theory*, 204, 105520. https://doi.org/10.1016/j.jet.2022.105520

Kiley, M. T. (2022). Fluctuations in the risk of a large increase in unemployment. Journal of Money, *Credit and Banking*, 54(5), 1407–1424. https://doi.org/10.1111/jmcb.12888

Kurzy.cz. (n.d.). *Nezaměstnanost – dlouhodobý vývoj.* https://www.kurzy.cz/makroekonomika/nezamestnanost/

Lacy, S., Watson, B. R., Riffe, D., & Lovejoy, J. (2015). Issues and best practices in content analysis. *Journalism & Mass Communication Quarterly, 92*(4), 791–811. https://doi.org/10.1177/1077699015607338

Latner, J. P. (2022). Temporary employment in Europe: Stagnating rates and rising risks. *European Societies*, 24(4), 383–408. https://doi.org/10.1080/14616696.2022.2072930

Martín-Román, A. L., Cuéllar-Martín, J., & Moral, A. (2023). Effective unemployment: A stochastic cost frontier approach. *Bulletin of Economic Research*, 75(1), 5–39. https://doi.org/10.1111/boer.12335

Ministerstvo práce a sociálních věcí. (n.d.). *MPSV data – databáze nezaměstnanosti.* https://data.mpsv.cz

Nicoli, F., et al. (2024). Labour market risks and preferences for EU unemployment insurance: The effect of automation, globalization and migration concerns. European Political Science Review. *Advance online publication*. https://doi.org/10.1017/S1755773924000316

Petrúsek, I., & Basna, K. (2025). Structural and cyclical unemployment and redistribution support in Europe: The moderating role of welfare state size. *West European Politics*. Advance online publication. https://doi.org/10.1080/01402382.2025.2556601

Pi, J., & Duan, S. X. (2023). Appropriation, rural-urban migration, minimum wage and unemployment: A general equilibrium approach. *Australian Economic Papers*, 62(3), 430–456. https://doi.org/10.1111/1467-8454.12300

Posta, V. (2023). The disaggregation of the projected impacts of automation in the regional labour markets between 2019 and 2030: Case of the Czech Republic. *Regional Statistics*, 13(3), 487–509. https://doi.org/10.15196/RS130305

Priede, J. (2023). Productivity challenges in Europe during the COVID-19 pandemic. *European Integration Studies*, 17, 99–107. https://doi.org/10.5755/j01.eis.1.17.34019

Rolník, O. (2023). The influence of the economic disparities between regions on political polarisation in the Czech Republic. *Scientific Papers of the University of Pardubice – Series D: Faculty of Economics and Administration*, 31(1), Article 1614. https://doi.org/10.46585/sp31011614

Zubíková, A., Veselá, K., & Smolák, P. (2023). Evaluation of the Antivirus A programme in the Czech Republic during the COVID-19 pandemic. *International Journal of Economic Sciences*, 12(1), 178–205. https://doi.org/10.52950/ES.2023.12.1.009

Contact address of the authors:

Kateřina Jíchová, Institute of Technology and Business in České Budějovice, School of Expertness and Valuation, Okružní 5170/10, 37001 České Budějovice, Czech Republic, e-mail: 28521@mail.vstecb.cz

Ing. Vilém Kovač, PhD., Institute of Technology and Business in České Budějovice, School of Expertness and Valuation, Okružní 5170/10, 37001 České Budějovice, Czech Republic, e-mail: kovac@mail.vstecb.cz

THEORETICAL STUDIES

Modernization of Sports Governance in Slovakia After the Establishment of the Ministry of Tourism and Sports

Milena Švedová[1]

[1] Institute of Technology and Business in Prešov, Faculty of Economics, Management and Marketing

Abstract

The study analyzes the transformation of sports governance in Slovakia following the establishment of the Ministry of Tourism and Sports of the Slovak Republic (MTSR SR) in 2024. Using qualitative and analytical approaches, the research examines organizational structure, financing, coordination, and professionalization within the Slovak sport management system. Data from legal and strategic documents, institutional reports, and expert interviews were synthesized. Results indicate that the new ministry improved strategic coherence but persistent issues remain in coordination, financing, and professional capacity. The paper proposes directions for modernization based on the principles of good governance, transparency, and cross-sectoral cooperation.

Keywords: sports governance, public policy, Slovakia, Ministry of Tourism and Sports, good governance, financing, professionalization.

Introduction

Sports governance represents a multidimensional public policy area integrating planning, organization, financing, and evaluation at all social levels. In Slovakia, sports governance has evolved alongside political decentralization and Europeanization, responding to growing expectations of transparency and effectiveness (Henry & Lee, 2004; Chappelet & Mrkonjic, 2019).

A milestone was the creation of the Ministry of Tourism and Sports of the Slovak Republic (MTSR SR), which in 2024 assumed responsibility for sports policy previously managed by the Ministry of Education, Science, Research and Sports. The reform aimed to enhance coordination, strengthen strategic direction, and align sports with tourism and regional development (Ministry of Tourism and Sports, 2024).

Despite progress, challenges remain in inter-institutional coordination, financing mechanisms, and professionalization. Slovakia lacks a comprehensive long-term strategy linking national objectives to regional realities, while fragmentation among actors undermines policy efficiency (European Commission, 2023). This study evaluates the structure and effectiveness of Slovak sports governance after the reform and formulates recommendations for modernization.

Results

1. Organizational and Institutional Structure

The establishment of Ministry of Tourism and Sport has created an independent vertical for sports policy and improved strategic visibility. The ministry coordinates through its Sports Section and cooperates with 97 national sports federations and over 11,000 registered clubs (MTS SR, 2025). However, coordination gaps persist—only 43 % of municipalities report aligning local strategies with national documents. Regional staffing is insufficient; two-thirds of municipalities lack a dedicated sports manager, indicating weak administrative capacity.

2. Sports Financing

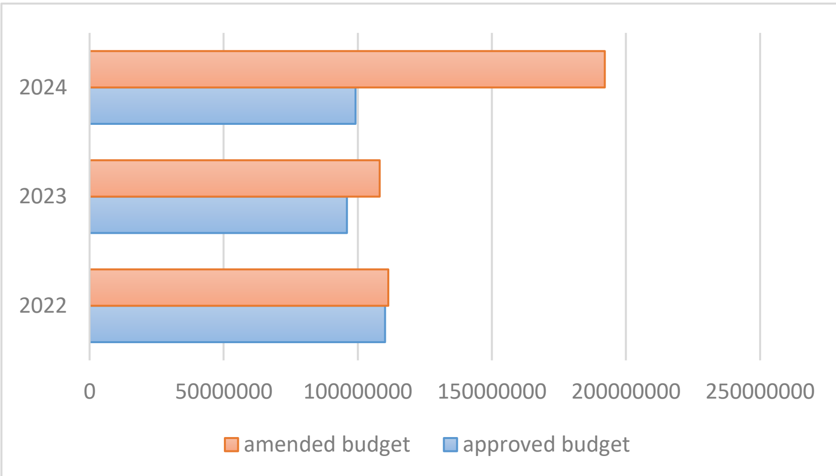
Public financing remains the dominant pillar of the sports system in the Slovak Republic. According to the Ministry of Tourism and Sports of the Slovak Republic (MTSR SR), the total state budget allocation for sport in 2025 amounts to €219.8 million. These resources are distributed primarily to recognized sports programs (72 %), followed by investments in sports infrastructure (18 %), youth sport development (6 %), and activities related to research, analysis, and strategic planning in sport (4 %) (MTSR SR, 2025). This structure reflects a continued emphasis on the support of organized and competitive sport, while comparatively limited funding is allocated to analytical and evidence-based policy development.

The adoption of Act No. 440/2015 Coll. on Sport introduced a transparent, formula-based mechanism for the redistribution of public funds, aimed at reducing subjectivity and political influence in funding decisions. Despite its conceptual strengths, the practical implementation of this system continues to face challenges. Delays in fund allocation, administrative burden, and inconsistencies in reporting requirements reduce the overall efficiency of the financing process. Moreover, empirical evidence suggests that only approximately one-third of national sports federations systematically assess the effectiveness and outcomes of received subsidies, indicating a significant gap in performance monitoring and financial accountability.

In addition to public funding, private financial resources—including sponsorships, membership fees, donations, and commercial activities—account for an estimated 22-25 % of total sports financing in Slovakia. This proportion remains substantially below the European Union average, which ranges between 40-45 % (European Commission, 2023). The relatively low level of private investment highlights structural weaknesses in the Slovak sports economy, such as limited commercialization of sport, insufficient attractiveness for sponsors, and underdeveloped mechanisms of cooperation between the public and private sectors. In this context, the introduction of targeted tax incentives, enhanced legal frameworks for sponsorship, and the systematic development of public-private partnerships (PPP) represent key strategic opportunities for diversifying funding sources and increasing financial sustainability.

Financing is also a central component of the National Sports Development Program, which aims to ensure long-term, balanced growth of sport across performance, participation, and infrastructural dimensions. The accompanying graph illustrates the evolution of financial resources allocated to sports development in Slovakia through the state budget. The data demonstrate a gradual increase in public expenditure on sport over recent years, while simultaneously revealing fluctuations that reflect broader economic conditions and shifting governmental priorities. These trends underscore the importance of strategic financial planning, multi-annual budgeting, and stronger links between funding allocation and clearly defined developmental objectives.

Graph 1: Allocation of funds to sport



Source: Own.

3. Professionalization

The level of professionalization within sports organizations in Slovakia remains limited and represents a significant structural constraint to the development of the sector. Empirical data indicate that 61 % of surveyed sports organizations are managed predominantly by volunteers who lack formal education in management, governance, or sports administration. Furthermore, only 27 % of organizations have established internal systems for the continuous education and professional development of their managerial staff. This reliance on voluntary management, while reflecting strong civic engagement, simultaneously limits organizational capacity, particularly in areas requiring specialized expertise.

In a comparative regional context, Slovakia falls behind neighboring countries with more advanced governance structures. For instance, in Slovenia approximately 70 % of national sports federations employ professional managers with defined competencies and contractual responsibilities (Kolar, 2022). The absence of a comparable level of professional staffing in Slovak sports organizations negatively affects long-term strategic planning, marketing and communication activities, financial management, and the ability to attract external funding, including private sponsorship and European project-based resources.

Limited managerial capacity also reduces organizational resilience and adaptability to changing policy environments and economic conditions. Without adequately trained professionals, sports organizations struggle to implement modern management practices, performance evaluation mechanisms, and innovation-driven approaches. Strengthening professionalization through targeted education programs, dual career pathways for sports managers, and financial incentives for employing qualified personnel should therefore be considered a key priority in national sports policy.

4. Governance and Transparency

Effective governance and transparency constitute fundamental prerequisites for the sustainable development of sport and for maintaining public trust in sports institutions. In Slovakia, the establishment of the Sports Information System (SIS) represents an important step toward centralized data collection and increased transparency. However, in practice, the system is characterized by incomplete datasets, irregular updates, and limited interoperability with other public databases. These shortcomings significantly reduce its usefulness for evidence-based policymaking, monitoring of public expenditures, and strategic decision-making at both national and organizational levels.

The lack of integrated digital governance tools further constrains the ability of public authorities and sports federations to evaluate performance, assess policy impacts, and identify systemic risks. As a result, decision-making processes often rely on fragmented or outdated information, which undermines the efficiency and credibility of sports governance.

Ethical standards and principles of transparency are applied unevenly across sports organizations. While some federations have implemented clear accountability structures, internal control mechanisms, and codes of ethics, others continue to operate with ambiguous lines of responsibility and insufficient oversight. According to Transparency International Slovakia (2024), persistent deficiencies in governance frameworks increase the risk of conflicts of interest, ineffective use of public resources, and reputational damage to the sports sector as a whole. Addressing these challenges requires the consistent enforcement of governance standards, enhanced digitalization, and the systematic monitoring of compliance with ethical and transparency principles (Transparency International Slovakia, 2024).

Discussion

The research confirms that establishing MTSR SR was a positive structural reform enhancing policy coherence and visibility of sport as an independent area of governance. Yet institutional integration remains incomplete. Slovakia operates within a multi-level governance framework (Hooghe & Marks, 2003), where effectiveness depends on coordination across vertical (state–region–municipality) and horizontal (sectoral) relations.

Current vertical control is strong, but horizontal collaboration among ministries, federations, and local actors is weak. Better inter-sectoral coordination—especially with education, public health, and tourism—could generate synergistic benefits (OECD, 2022).

Transparency and data management represent critical weaknesses. Compared with Austria and Slovenia, where digital dashboards provide real-time monitoring, Slovakia lacks systematic evaluation of outcomes (European Union Work Plan for Sport 2021–2027, EU Council, 2021).

Sustainable development of sport also requires integrating the principles of good governance: accountability, participation, equity, and integrity (Council of Europe, 2018). These principles must guide funding allocation, human resource development, and anti-corruption measures. The future direction should move toward a "Smart Sport Governance" model using digitalization and data analytics for strategic decision-making.

Conclusion

The establishment of the Ministry of Tourism and Sports of the Slovak Republic (MTSR SR) has significantly strengthened the institutional and strategic framework of national sports policy. By consolidating competencies previously dispersed across multiple governmental bodies, the creation of the ministry represents an important step toward more coherent governance and long-term planning in the sports sector. At the same time, the analysis presented in this study reveals a number of persistent systemic deficiencies that continue to limit the effectiveness and sustainability of sports development in Slovakia.

A key challenge remains the insufficient coordination among national, regional, and local levels of governance. Fragmented responsibilities and limited vertical cooperation weaken policy implementation and reduce the capacity to respond effectively to local needs. In parallel, the current model of sports financing is characterized by uneven distribution of resources and a lack of systematic evaluation of subsidy effectiveness, which undermines accountability and evidence-based decision-making.

The findings further highlight a low level of professionalization within sports organizations, particularly in managerial and administrative roles. The widespread reliance on voluntary leadership, combined with limited access to formal managerial education, constrains strategic planning, financial control, marketing activities, and the ability to attract diversified funding sources. These shortcomings are closely linked to broader governance challenges, including inconsistent application of transparency and ethical standards and limited utilization of digital tools.

Insufficient digitalization and weak interconnection of information systems, including the Sports Information System, further restrict the capacity for data-driven policy formulation and monitoring. Moreover, the limited integration of sports policy with related sectors such as public health, education, and tourism represents a missed opportunity to fully exploit the cross-sectoral potential of sport as a tool for societal development.

Building a modern, transparent, and participatory sports system in Slovakia therefore requires a comprehensive and coordinated reform approach. Aligning national sports policy with European standards of good governance, professionalization, and accountability is essential. At the same time, greater emphasis should be placed on leveraging sport's contribution to public health promotion, social inclusion, education, and economic development. Only through such an integrated and evidence-based strategy can sport fulfill its full potential as a public good and a driver of sustainable development in Slovak society.

References

Antoni, M. H., Dhabhar, F. S., & Lutgendorf, S. K. (2023). Psychoneuroimmunology and Cancer: Mechanisms and Interventions. *Oxford University Press*.

Chappelet, J. L., & Mrkonjic, M. (2019). Basic Indicators for Better Governance in Sport. *Council of Europe*.

Council of Europe. (2018). Good Governance in Sport: European Principles. *Council of Europe Publishing*.

European Commission. (2023). Sport and Physical Activity: Special Eurobarometer 525. *Publications Office of the European Union*.

European Union Council. (2021). EU Work Plan for Sport (2021–2027). *Official Journal of the European Union, C 2021/32*.

Gábriš, T. (2020). The Status of Professional Players Between Self-Employed and Employee Status: State of the Art in Slovakia and In East-Central Europe. *Zbornik Pravnog Fakulteta Sveučilišta u Rijeci, 41*(3), 847–863.

Henry, I., & Lee, P. C. (2004). Governance and Ethics in Sport. *Governance and Ethics in Sport, Routledge*, 1–24.

Hooghe, L., & Marks, G. (2003). Unraveling the Central State, But How? Types of Multi-Level Governance. *Governance, 16*(4), 473–492. https://doi.org/10.1111/1468-0491.00258

Kolar, T. (2022). Professionalization of Sport Management in Central Europe. *European Sport Management Quarterly, 22*(3), 389–406.

Matušíková, D., Švedová, M., Dzurov Vargová, T., & Żegleń, P. (2020). An Analysis of the "European City of Sports" Project and Its Impact on the Development of Tourist Activity: The Example of Selected Slovakian Cities. *Turyzm/Tourism, 30*(1), 61–70. https://doi.org/10.18778/0867-5856.30.1.18

Ministry of Tourism and Sports of the Slovak Republic. (2023). Settlement of Financial Resources Provided in 2022. *MINCRS*. https://mincrs.sk/vyuctovanie-financnych-prostriedkov-poskytnutych-v-roku-2022/

Ministry of Tourism and Sports of the Slovak Republic. (2025). Draft Sports Development Strategy 2030. *Bratislava*.

National Council of the Slovak Republic. (2015). Act No. 440/2015 Coll. on Sport. *Slov-Lex*. https://www.slov-lex.sk

OECD. (2022). Boosting Sports and Physical Activity for Well-Being. *OECD Publishing*. https://doi.org/10.1787/4a5a54b9-en

Švedová, M., Dzurov Vargová, T., & Matušíková, D. (2019). Sports Manager in Physical Education and Sports and Its Management Method. *Journal of Global Science, 4*(1), 1–7.

Transparency International Slovakia. (2024). Integrity and Transparency in Slovak Sport. *Transparency International Slovakia*.

WHO. (2018). Global Action Plan on Physical Activity 2018–2030. *World Health Organization*.

Contact address of the author:

PaedDr. Milena Švédová, PhD., MBA, Institute of Technology and Business in Prešov, Faculty of Economics, Management and Marketing, Masarykova 22, 080 01 Prešov, Slovak Republik, e-mail: svedova@vste.sk

A statutory model of compensation for the use of works in artificial intelligence training as a proposal for systemic strengthening of copyright in the era of machine learning

Andrzej Madera[1]

[1]Academy of Justice in Warsaw, Faculty of Security and Legal Sciences

Abstract

The dynamic development of generative artificial intelligence has revealed the structural inadequacy of traditional copyright mechanisms for the mass, automated processing of data used in model training processes. Classic licensing systems, based on identifiable and individual access to a work, are unable to function in an environment where a single algorithm processes millions of protected content in a way that cannot be reproduced using existing regulatory tools. The article analyzes the legal and economic rationale behind the proposal to introduce a statutory compensation model for the use of works in artificial intelligence training, inspired by the European system of reprographic fees. The study attempts to demonstrate that this model can be an effective tool for balancing the interests of creators and technology companies, while strengthening the stability of the copyright system. It also points to the need to supplement future regulations with data transparency obligations and appropriate institutional instruments to enable the efficient redistribution of remuneration. The results of the analysis lead to the conclusion that statutory compensation can become the foundation for the sustainable development of the creative and technological ecosystem in an era of growing AI autonomy.

Keywords: Artificial intelligence; copyright, machine learning, reprographic fees, statutory compensation, text and data mining, generative AI models, protection of creators.

Introduction

Over the last decade, the process of training artificial intelligence systems has undergone a rapid transformation, primarily due to the development of generative models capable of processing, analyzing, and recombining huge data sets. This data covers a wide range of works, such as literary texts, press articles, photographs, images, and music recordings, most of which are protected by copyright. The current regulatory framework does not provide for mechanisms to adequately regulate the use of such extensive and diverse material, creating uncertainty for both creators and AI developers. The material contained in the submitted document clearly emphasizes that the fundamental problems concern not only the scale of the data, but also the way it is processed, which does not allow for the identification of individual works used in the algorithm training process.

The inability to link a specific work to its use in the training process makes it impossible to apply traditional licensing models designed for the precise and traceable use of materials. This issue is widely discussed in the literature on automatic data mining. Lemley (2024) notes that text and data mining (TDM) processes in the context of machine learning are radically different from classic copying and thus challenge existing concepts of exhaustion of rights. Geiger, Frosio, and Bulayenko (2018a; 2018b) emphasize that the TDM exemptions provided for in European Union law have been designed too narrowly to cover the mass use of content by AI systems. For this reason, it is necessary to create new legal solutions that are adequate to the technological realities.

Training AI models as a challenge to existing copyright mechanisms

The process of training AI models is based on the analysis of huge and heterogeneous data sets which, as the source document aptly points out, include millions of works processed in a way that cannot be traced using the methods used in classic licensing

Floridi and Chiariatti (2020) point out that a characteristic feature of generative models is their ability to create new, previously non-existent content thanks to their ability to extract and transform patterns from input data. This differs radically from the traditional reception of a work, in which exploitation is recognizable and its scope can be verified.

In European copyright law, the 2019 DSM Directive plays a special role, introducing two important regulations concerning text and data mining. Article 3 allows TDM for research purposes, while Article 4 provides for the possibility of TDM for commercial purposes, unless the rightholder objects. These regulations, although groundbreaking at the time of their adoption, do not solve the problem of mass training of AI systems, as they assume the possibility of an effective opt-out by the creator, which in practice is often unfeasible in an environment with billions of data points (Margoni & Kretschmer 2022). Truyens and Van Eecke (2014) point out that TDM as a data analysis method was not designed for large-scale generative machine learning, but as an information extraction technique. As a result, current legal regulations are not compatible with the way modern AI systems use data.

Similarly, practical problems related to collective licensing are raised in the literature on the subject. Senftleben et al. (2022) point out that collective management organizations do not have the tools to control or license the use of hundreds of millions of works simultaneously, which makes traditional licensing models structurally inefficient. The document clearly shows that any attempt to adapt the classic licensing system to the needs of AI training would lead to paralysis on both the technological and legal sides, and that any attempt at individual data licensing is practically impossible.

Inspiration from the European system of reprographic fees and the need for statutory compensation

The reprographic fee system, widely discussed in the literature on private copying (Oksanen & Välimäki 2005; Netanel 2003; Hugenholtz 2012), is one of the most successful examples of a legal tool that reconciles the mass use of works with the interests of creators. It allows for the legal copying of works for personal use, while providing creators with indirect remuneration collected from manufacturers of copying devices. Fisher (2004) notes that the strength of compensation systems lies in moving away from attempts to track specific acts of copying and focusing on compensating for the economic effects of using someone else's work.

The conclusion in the submitted document that a similar model can be applied to AI training is strongly justified by the system

In both cases, we are dealing with mass exploitation of content, which is technically impossible to monitor and license individually. Adapting the idea of private copying levies to AI training processes could therefore involve establishing a statutory levy on entities developing AI models, with the revenue redistributed to creators through a collective management organization or a specialized public institution. Geiger and Iaia (2024) argue that statutory compensation is the most realistic way to ensure remuneration for creators when the identification of the works used is technically unfeasible.

The importance of data transparency and the need for institutional support

The literature also points to the need to introduce solutions that increase the transparency of AI training processes. Jernite (2023) emphasizes that the obligation to disclose training data sources is a minimum requirement for the functioning of any efficient compensation model. The source document also notes that fees alone are not sufficient without the creation of a register of data used in model training and an institution capable of managing the flow of funds.

These solutions would contribute to increasing the trust of creators, reducing information asymmetry, and improving the quality of remuneration redistribution.

Conclusion

An analysis of copyright regulations and a review of the literature clearly indicate that the current system of licensing works is not adapted to artificial intelligence technology, whose fundamental feature is the mass, unidentifiable, and automatic use of data. The statutory compensation model, inspired by the reprographic fee system, is a promising proposal for resolving the conflict between the interests of creators and the need for further development of AI technology. This model is consistent with the European tradition of copyright protection, while at the same time being implementable without the need for radical transformation of existing institutional structures.

The literature clearly confirms that the lack of adequate legal solutions threatens both the destabilization of the creative ecosystem and an increase in legal risks for the technology sector. Therefore, statutory compensation appears not as an obstacle to development, but as a condition for the sustainable coexistence of creativity and innovation in the future. The source document also emphasizes that the introduction of such a mechanism could reduce the level of legal disputes and strengthen the foundations of a market based on respect for creators' rights and transparency of technological processes.

References

Floridi, L., & Chiariatti, M. (2020). GPT-3: Its Nature, Scope, Limits, and Consequences. *Minds & Machines, 30*, 681–694.

Geiger, C. (2021). The Missing Goal-Scorers in the Artificial Intelligence Team: Of Big Data, the Fundamental Right to Research and the Failed Text and Data Mining Limitations in the CDSM Directive. *Intellectual Property and Sports: Essays in Honor of P. Bernt Hugenholtz, Kluwer Law International*, 383–394.

Geiger, C., & Iaia, V. (2024). The Forgotten Creator: Towards a Statutory Remuneration Right for Machine Learning of Generative AI. *Computer Law & Security Review, 52*, 1–9.

Geiger, C., Frosio, G., & Bulayenko, O. (2018). Crafting a Text and Data Mining Exception for Machine Learning and Big Data. *Intellectual Property and Digital Trade, Geneva/Strasbourg*, 95–112.

Geiger, C., Frosio, G., & Bulayenko, O. (2018). Text and Data Mining in the Proposed Copyright Reform. *International Review of Intellectual Property and Competition Law, 49*, 814–844.

Hugenholtz, P. B. (2012). The Story of the Tape Recorder and the History of Copyright Levies. *Copyright and the Challenge of the New, Wolters Kluwer*.

Lemley, M. (2024). How Generative AI Turns Copyright Upside Down. *Columbia Science & Technology Law Review, 25*(2), 190–212.

Lucchi, N. (2023). ChatGPT: A Case Study on Copyright Challenges for Generative AI Systems. *European Journal of Risk Regulation, 15*(3), 602–624.

Margoni, T., & Kretschmer, M. (2022). A Deeper Look Into EU TDM Exceptions. *GRUR International, 71*, 685–701.

Netanel, N. (2003). Impose a Noncommercial Use Levy to Allow Free Peer-to-Peer Sharing. *Harvard Journal of Law & Technology, 17*(1), 2–83.

Oksanen, V., & Välimäki, M. (2005). Copyright Levies as an Alternative Compensation Method. *Review of Economic Research on Copyright Issues, 2*(2), 25–39.

Senftleben, M., Margoni, T., et al. (2022). Ensuring Visibility and Accessibility of European Creative Content. *JIPITEC, 13*, 67–86.

Truyens, M., & Van Eecke, P. (2014). Legal Aspects of Text Mining. *Computer Law & Security Review, 30*, 153–170.

Wang, J. T., Deng, Z., et al. (2024). An Economic Solution to Copyright Challenges of Generative AI. *arXiv*.

Contact address of the author:

Andrzej Madera, Academy of Justice in Warsaw, Faculty of Security and Legal Sciences, Wisniowa 50, 02-520 Warsav, Poland, e-mail: amadera@poczta.onet.pl

The ethics of cryptocurrencies: between financial freedom and social responsibility

Wojciech Słomski[1]

[1] Institute of Technology and Business in Prešov, Faculty of Economics, Management and Marketing

Abstract

This article provides an interdisciplinary ethical analysis of cryptocurrencies, positioning them as a complex socio-cultural and technological phenomenon that transcends traditional finance. By bridging the gap between moral philosophy, economics, law, and social theology, the study explores the fundamental tension between the promise of financial freedom and the necessity of social responsibility.

The analysis evaluates three research hypotheses focusing on the emergence of moral risks, the role of institutions in mitigating inequality, and the potential of cryptocurrencies to serve the common good. Using the philosophical frameworks of Aristotle, Kant, and Rawls, the text examines critical issues such as transaction anonymity, the environmental impact of proof-of-work mechanisms, and the paradox of centralized power within decentralized systems. Furthermore, it addresses the regulatory landscape, specifically the EU's MiCA regulation, and contrasts the use of crypto-assets in developed versus developing economies.

The study concludes that while cryptocurrencies offer significant potential for financial inclusion and individual autonomy, they can only be ethically integrated into the global system if governed by a new paradigm of transparency, solidarity, and environmental care. Ultimately, the article argues for a shift from a purely economic profit logic to an ethical framework rooted in justice and the common good.

Keywords: Cryptocurrency Ethics, Financial Freedom, Social Justice, Common Good, Environmental Responsibility.

Introduction

Since Satoshi Nakamoto published his manifesto Bitcoin: A Peer-to-Peer Electronic Cash System (Nakamoto 2008) in 2008, cryptocurrencies have become one of the most discussed technological and economic phenomena of the 21st century. This phenomenon extends beyond the sphere of finance, entering the fields of law, philosophy, sociology, and social theology. For some, cryptocurrencies are a promise of economic emancipation, freedom from state and central bank control; for others, they are a source of risk: destabilization of monetary systems, speculation, and growing inequalities (Golumbia 2016; Prasad 2021).

Previous research on cryptocurrencies has focused mainly on their technological and economic aspects (Narayanan et al. 2016; De Filippi & Wright 2018), with less systematic attention paid to ethical issues. There are studies on the risks associated with money laundering and the financing of criminal activities (Foley, Karlsen & Putniņš 2019), as well as studies on their environmental impact (Stoll, Klaaßen & Gallersdörfer 2019; de Vries 2022). However, there is a lack of a synthetic approach that would combine philosophical, legal, economic, and social analysis in the context of fundamental questions about the common good.

The aim of this article is to highlight the tension between financial freedom and social responsibility in the world of cryptocurrencies. The analysis is interdisciplinary, covering:

- moral philosophy (Aristotle, Kant, Rawls, MacIntyre),
- economics and finance (Keynes, Hayek, Prasad),
- social sciences and law (Weber, De Filippi & Wright, BIS, EU regulations),
- social theology (John Paul II, Benedict XVI, Francis).

I formulate three research hypotheses:

- H1: The financial freedom offered by cryptocurrencies inevitably gives rise to new forms of moral risk and social inequality.
- H2: Institutions—states, stock exchanges, international organizations—can mitigate these risks, but they require a new ethical paradigm based on transparency and solidarity.

- H3: Cryptocurrencies can become a tool for promoting the common good only if they are incorporated into an ethical framework that includes care for the most vulnerable and environmental responsibility.

The article is based on a critical analysis of the literature on the subject, combining philosophical, economic, and legal sources. I use both classical texts (e.g., Aristotle's *Nicomachean Ethics*; Rawls' A *Theory of Justice)* and contemporary studies (De Filippi & Wright 2018; Prasad 2021). The analysis is normative and diagnostic in nature: the aim is not merely to describe the phenomenon of cryptocurrencies, but to attempt to answer the question of what ethical framework should shape their presence in the world of finance and society.

What is new about this study is the systematic combination of technological, ethical, and social perspectives. The article does not limit itself to the question of "whether cryptocurrencies are good or bad," but explores how they can be ethically integrated into the global economic system.

Cryptocurrencies as a technological and social phenomenon

Cryptocurrencies should be understood not only as financial tools, but also as a complex socio-cultural phenomenon. At their inception, they were closely linked to the ideas of the cypherpunk movement, which developed in the 1980s and 1990s. David Chaum had already proposed a payment system that would ensure complete anonymity for transaction participants, which was intended to counterbalance growing state and corporate surveillance (Chaum 1985: 1030-1034). Timothy C. May, in his *Crypto Anarchist Manifesto* (1992), presented a vision of a world in which cryptography would become the basis of a new social order, free from institutional control.

Bitcoin—designed as a decentralized distributed ledger system—was the practical embodiment of these ideas. The use of blockchain technology allowed trust to be transferred from state and banking institutions to a mathematical consensus algorithm. As Maurer, Nelms, and Swartz (2013: 262-265) note, Bitcoin is not only a medium of exchange, but also a performative social experiment, testing the limits of what money can be and what kind of community can form around it.

This phenomenon should be seen in the broader context of a networked society, in which digital technologies are redefining not only the economy but also social relations. Golumbia (2016: 53-59) points out that cryptocurrency narratives combine elements of free-market libertarianism, techno-anarchism, and distrust of state institutions. This ideological mix makes cryptocurrencies not only financial instruments, but also a kind of cultural project in which technology becomes a vehicle for political ideas.

From the perspective of social theory, cryptocurrencies can be interpreted as an example of what Manuel Castells referred to as the "new morphology of society" (*The Rise of the Network Society*, 1996). Relationships in the blockchain ecosystem—between miners, developers, investors, and users—are not hierarchical but networked, based on participation and the continuous flow of information. However, as BIS research (2018: 91-94) points out, the promise of decentralization often proves illusory: in practice, a few exchanges and mining groups dominate, leading to a concentration of power.

Cryptocurrencies have also become a social phenomenon in a symbolic sense. Terms such as hodl, to the moon, and diamond hands function as elements of community language, as do the rituals of participation in forums and social media. These practices—seemingly trivial—point to the emergence of new forms of collective identity associated with participation in digital markets.

Ultimately, cryptocurrencies should be treated as a hybrid: a technological innovation, an ideological movement, and a social practice. This combination means that ethical analysis cannot be limited to financial categories. Reflection is needed on their role in shaping values, social structures, and new forms of participation in public life.

Financial freedom and decentralization – idea and practice

One of the central slogans of the cryptocurrency narrative is financial freedom. The manifestos of the cypherpunk movement and the early discussions around Bitcoin express the belief that the traditional monetary system based on central banks and intermediary institutions limits individual autonomy. As Hayek wrote in Denationalisation of Money (1976: 22-29), the state's monopoly on money issuance encourages abuse and inflation, and free currency competition could restore a just economic order. Cryptocurrencies, in a sense, fulfill this postulate by creating an alternative system in which users can make transactions without the intermediation of state institutions.

In this context, financial freedom primarily means the ability to freely dispose of one's own resources and protect one's privacy. The cryptographic mechanisms used in blockchain ensure the pseudonymity of transactions, and the lack of a central administrator eliminates the risk of arbitrary censorship. As Berlin (1991: 37-39) emphasizes, negative freedom consists in the absence of external restrictions – in the world of cryptocurrencies, this manifests itself in the absence of the need to use banking services or comply with the state's monetary policy.

However, as Rawls (1971: 243-246) notes, freedom must be linked to the principle of justice. In practice, the decentralization of cryptocurrencies does not always mean greater equality. Research by the BIS (2018: 96-99) shows that most cryptocurrency transactions and resources are concentrated in the hands of a small group of investors and exchanges. This creates a paradox: a tool designed to be decentralized creates new centers of power, often less transparent than traditional institutions.

MacIntyre (2007: 187-192) pointed out that individual freedom only makes sense within social practices rooted in the community. In the case of cryptocurrencies, the question arises: does financial freedom become an illusion if its realization means the risk of losing funds as a result of a hacker attack, speculation, or stock market fraud? Freedom detached from responsibility—both individual and institutional—leads to anarchy, not emancipation.

The practical dimension of financial freedom is particularly evident in countries where the banking system is unstable or repressive. The examples of Venezuela and Nigeria show that cryptocurrencies can serve as a tool for protecting assets in crisis situations (Prasad 2021: 187-191). At the same time, in countries with stable financial institutions, cryptocurrencies more often function as an object of speculation than as a real alternative to fiat money.

Decentralization, which is the foundation of the blockchain idea, faces practical limitations due to technical and economic constraints. The proof-of-work system requires significant energy and specialized equipment, which leads to the concentration of computing power in large mining farms. Alternative mechanisms, such as proof-of-stake, promoted by Buterin

(2022: 77-84), among others, are an attempt to reconcile decentralization with greater efficiency and sustainability.

Financial freedom and decentralization, while attractive in theory, reveal their ambivalence in practice. On the one hand, they open up space for individual autonomy and emancipation; on the other, without ethical and regulatory frameworks, they can lead to new forms of inequality, exploitation, and exclusion.

Ethical risks: anonymity, fraud, crime

Anonymity, one of the most frequently highlighted advantages of cryptocurrencies, has a dual ethical dimension. On the one hand, it protects individual privacy, a fundamental value in a democratic society. On the other hand, however, it creates space for criminal activities, from money laundering to financing drug trafficking and terrorism. As Foley, Karlsen, and Putniņš (2019: 1802-1805) have shown, a significant percentage of early Bitcoin transactions were linked to illegal markets, such as the infamous Silk Road.

The ethical problem, therefore, is the ambivalence of technology: a tool of emancipation can also be a tool of destruction. Kant (1785/2011: 53-56) emphasized in his Groundwork of the Metaphysics of Morals that the autonomy of the individual must always be subordinated to the principle of universal moral law. If anonymity serves to protect dignity and freedom, it is ethically positive; if, on the other hand, it becomes a mechanism for masking exploitation and violence, it leads to a distortion of the very idea of freedom.

Investment and speculative frauds pose an additional risk. Due to their decentralized nature, cryptocurrencies often operate outside the supervision of public institutions. This has led to a proliferation of pyramid schemes and fraudulent ICOs (Initial Coin Offerings). As Keynes (1936/2007: 157-160) notes, financial markets have a natural tendency toward irrational collective behavior. In the world of cryptocurrencies, this effect is exacerbated by the lack of regulation and the mass dynamics of social media.

Rawls (1971: 302-307) emphasized that social institutions must be designed to protect the weakest participants. In practice, however, the victims of crypto fraud are most often small investors who do not have sufficient technological and financial knowledge. Responsibility therefore falls not only on individuals, but also on cryptocurrency exchanges, which should be guided by the principles of transparency and due diligence.

The ethical risk associated with cryptocurrencies also concerns their potential use in terrorist financing. A UN report (2019: 214-219) indicates that criminal and terrorist groups are experimenting with cryptocurrencies as a means of circumventing financial control systems. Although the scale of this phenomenon is smaller than media narratives suggest, this problem reveals the limits of the concept of financial freedom: absolute freedom can be conducive to the destruction of the common good.

The perspective of virtue philosophy, developed by Aristotle in Nicomachean Ethics (2011: 112-116), indicates that the proper use of financial tools requires the development of prudence (phronesis). Technology itself is neither good nor bad—it is only given an ethical dimension by social practice, in which participants are guided by specific values. Anonymity, speculation, and crime are symptoms of a lack of prudence and the virtue of moderation in the world of cryptocurrencies.

In summary, the ethical risks of cryptocurrencies stem from the tension between individual freedom and social responsibility. Privacy protection and financial autonomy can be positive values if they are balanced by mechanisms of transparency, investor education, and institutional accountability. Without this, freedom becomes fertile ground for chaos and destruction.

Economic and regulatory dimensions

Cryptocurrencies are significantly changing the economic landscape by challenging the traditional functions of money. According to the classic definition, money has three basic roles: a medium of exchange, a measure of value, and a store of value (Keynes 1936/2007: 45-49). In practice, however, most cryptocurrencies do not fully fulfill these functions. As a medium of exchange, they are ineffective due to their high volatility; as a store of value, they are unstable; and as a unit of account, they are speculative and risky.

The BIS report (2018: 95-101) points out that although cryptocurrencies have provided innovation in payment technology, in their current form they cannot compete with fiat currencies as common means of payment. Prasad (2021: 147-153), on the other hand, emphasizes that their significance lies more in their transformative impact on finance—they pave the way for the development of central bank digital currencies (CBDCs) and new forms of market regulation.

The regulatory dimension of cryptocurrencies remains the subject of intense debate. In US case law, SEC v. W. J. Howey Co. (328 U.S. 293, 1946) provided the basis for the definition of an investment instrument. On this basis, the modern SEC is analyzing whether certain cryptocurrencies and tokens can be treated as securities, which entails registration and supervisory obligations.

In Europe, the adoption of Regulation (EU) 2023/1114 of the European Parliament and of the Council on markets in crypto-assets (MiCA) was a breakthrough. This act introduces a uniform legal framework for the issuance, trading, and protection of investors in the crypto-asset market. As De Filippi and Wright (2018: 203-208) emphasize, law in the blockchain era is no longer just a "rule of code," but a dynamic interaction between technology, institutions, and social values.

The economic dimension of cryptocurrencies also raises questions about their impact on the stability of financial systems. The IMF report (2021: 77-84) points out that the widespread adoption of cryptocurrencies may hamper monetary policy and weaken credit transmission mechanisms. At the same time, however, blockchain technology can support innovation in cross-border payments, reducing transfer costs and improving financial inclusion.

From an ethical perspective, the key question remains: should regulations restrict individual freedom in the name of protecting the common good? Rawls (1971: 244-247) argued that fair institutions must strike a balance between freedom and security. In the case of cryptocurrencies, this means the need to develop a regulatory model that, on the one hand, would protect users and the stability of the system, and on the other, would not stifle innovation.

In practice, there is a tendency towards compromise: countries are trying not to ban cryptocurrencies, but to regulate their trading, enforce AML (anti-money laundering) requirements, and introduce licensing mechanisms for exchanges. This policy is in line with the principle that technology should be tamed and incorporated into the legal framework, rather than completely eliminated.

In summary, the economic and regulatory dimensions of cryptocurrencies reveal a fundamental tension: between their innovative potential and the risk of destabilization. It is in this space that the key task of ethics becomes apparent—to indicate the boundaries within which financial freedom becomes social responsibility.

Environmental ethics and environmental costs

One of the most criticized aspects of cryptocurrencies, especially those based on the proof-of-work (PoW) mechanism, is their impact on the natural environment. The process of mining Bitcoin and other PoW cryptocurrencies requires enormous amounts of electricity. Stoll, Klaaßen, and Gallersdörfer (2019: 1649-1652) estimated that the annual energy consumption of the Bitcoin network was comparable to that of entire medium-sized countries, leading to significant CO_2 emissions. De Vries (2022: 2168-2171) points out that despite some progress in the use of renewable energy, most miners use cheap coal-based energy, which exacerbates the problem of climate change.

From the perspective of environmental ethics, the question arises as to whether the benefits of financial freedom and technological innovation can justify the degradation of the ecosystem. In his encyclical Laudato si' (2015: §55-61), Francis emphasizes that the ecological crisis is also a moral crisis, and that all economic activity should be subordinated to concern for the common good and the protection of creation. Aristotle (2011: 117-120), in turn, pointed out in Nicomachean Ethics that the virtue of moderation presupposes the ability to restrain excessive desires, which in the context of cryptocurrencies means the need to limit immoderate energy consumption for the sake of profit.

The ecological issue also has a dimension of global justice. The largest mining farms are located in countries with cheap energy, often at the expense of local communities, which suffer from pollution and environmental degradation. Rawls (1971: 301-305) reminded us that fair institutions must take into account the interests of those who have no voice in the decision-making process. In the case of cryptocurrencies, the victims are often residents of peripheral regions, while the beneficiaries are global financial elites.

Attempts to address the problem come in the form of alternative consensus mechanisms. Proof-of-stake (PoS), promoted by the creators of Ethereum, significantly reduces energy consumption—according to Buterin (2022: 142-145), by more than 99% compared to PoW. However, the ethical question remains open: is the transition to PoS a real solution to the problem, or rather a shift of responsibility to other areas (e.g., concentration of power among large token holders)?

MacIntyre (2007: 192-196) emphasized that truly ethical action is not about maximizing individual benefits, but about building a community based on values. In this light, the cryptocurrency community faces a challenge: will it be able to incorporate the principle of environmental responsibility into its practices, or will it stick to the logic of unlimited profit?

In summary, the environmental costs of cryptocurrencies reveal a fundamental tension between technological freedom and responsibility towards creation. Ecological ethics demands that the future of digital finance be built not at the expense of the planet, but in harmony with it.

The philosophical foundations of cryptocurrency ethics: from Aristotle to Rawls

An ethical analysis of cryptocurrencies requires placing it in the broader context of moral philosophy. The history of ethics provides tools for understanding phenomena which, although technologically new, replicate age-old dilemmas related to freedom, justice, and the common good.

Aristotle, in Nicomachean Ethics (2011: 109-113), pointed out that the goal of human action is to achieve eudaimonia, understood as a full life in accordance with virtue. Cryptocurrencies can be analyzed in this spirit: do they contribute to the development of virtues such as prudence (phronesis) and moderation, or do they rather encourage greed and speculation? It seems that they are morally neutral in themselves, but the practices of their users determine their ethical significance.

Kant (1785/2011: 67-72) in Groundwork of the Metaphysics of Morals emphasized that the autonomy of the individual requires submission to the categorical imperative: one should act only according to a maxim that one can will to be a universal law. In the world of cryptocurrencies, this principle applies to the assessment of anonymity and decentralization.

As long as they serve to protect dignity and freedom, they can be considered ethically acceptable; however, if they become a tool for exploitation, fraud, or crime, they contradict Kant's idea of morality.

Rawls (1971: 54-59) proposes a theory of justice as fairness, in which social institutions must be designed to maximize the benefits of the least privileged. From this perspective, cryptocurrencies should be evaluated not by how much profit they bring to individuals, but by how they affect the communities most vulnerable to exclusion. If they are a tool for financial inclusion in countries without a stable banking system, they can be considered consistent with the principle of justice. However, if they exacerbate inequalities, they become ethically problematic.

The neo-Thomist tradition and the social teaching of the Church, in which the common good is placed above individual interests, also remain an important point of reference. Benedict XVI's encyclical Caritas in Veritate (2009: §36-38) reminds us that an economy without ethics becomes a source of alienation. In this sense, cryptocurrencies, designed and used solely for profit, are incomplete—they need to incorporate the perspective of solidarity.

MacIntyre (2007: 191-194), in his critique of liberalism, points out that ethics cannot be reduced to the autonomous choices of the individual, but must be rooted in community practices. Cryptocurrencies, as a technological and social project, highlight this very problem: is it possible to create a community of practice based on values rather than solely on economic interests?

In summary, the philosophical foundations of cryptocurrency ethics point to the need to combine perspectives: Aristotle's concern for virtue, Kant's principle of universalization, and Rawls's requirement of social justice ( ). Only such a synthesis allows us to grasp the full extent of the ethical challenges posed by the blockchain revolution.

Law, code, and ethics – cryptocurrencies in a normative context

The relationship between law and ethics in relation to cryptocurrencies is particularly complex. Positive law is a system of norms that are binding and enforceable by state institutions, while ethics points to values that should shape human actions, regardless of whether they are formally sanctioned. In the case of cryptocurrencies, the two spheres meet and clash in a new, dynamic area of technology where traditional regulatory frameworks prove insufficient.

Lon L. Fuller (1969: 39-44) pointed to the existence of an "internal morality of law," encompassing principles such as generality, transparency, consistency, and enforceability of norms. Cryptocurrencies challenge this concept because their regulation requires reconciling the global nature of the blockchain network with local legal systems. The lack of uniform rules generates the risk of "regulatory arbitrage"—a situation in which entities move their activities to jurisdictions with the least restrictive regulations, thereby undermining the effectiveness of the law.

Roman law already distinguished between ius civile and ius gentium, pointing to the need for universal rules common to different communities (Justinian Digests 1985: Book I, Vol. 1). In a sense, cryptocurrencies reproduce this problem, demanding supranational normative solutions. Today's equivalent is, for example, the MiCA Regulation (2023), which aims to create a single market for crypto-assets in the European Union, counteracting the fragmentation of regulations.

However, the law is not always able to keep pace with technological innovation. Lawrence Lessig (1999: 85-89) formulated the thesis that "code is law," pointing out that digital architecture itself regulates user behavior. In the case of blockchain, consensus rules, smart contracts, and protocols constitute a normative framework parallel to statutory law. This raises the question: should the ethics of cryptocurrencies be based on code norms, or is it necessary to have an external, human-rooted set of values?

Rawls (1971: 55-58) reminds us that just institutions cannot be limited to the formal correctness of the law, but must reflect the values of the common good. In this spirit, cryptocurrency law should take into account not only investor protection, but also broader social and environmental considerations. Ethics is therefore an essential criterion for evaluating regulation: not every law is just, and a lack of regulation can lead to ethical chaos.

It is worth noting that the tension between ethics and law in the context of cryptocurrencies echoes a classic philosophical problem: should the law shape morality, or should morality set the limits of the law? Fuller (1969: 96-101) emphasized that without ethical foundations, law degenerates into pure technique of power. Cryptocurrencies, as a global phenomenon, demand precisely this integration: law based on ethics and ethics rooted in legal practices.

In summary, the normative context of cryptocurrencies reveals three levels: statutory law, technological code, and social ethics. Each of these is insufficient on its own, but their synergy offers an opportunity to create an order that not only regulates but also educates toward responsibility.

Cryptocurrencies, social justice, and global inequalities

The issue of social justice in the context of cryptocurrencies is one of the key ethical issues. Proponents of blockchain technology point out that cryptocurrencies can contribute to financial inclusion by providing access to payment systems for people excluded from traditional banking institutions. In developing countries, where banking infrastructure is underdeveloped, a mobile phone and internet access are all that is needed to participate in the global financial circulation (Prasad 2021: 187-191).

However, the enthusiastic narrative about the democratization of finance often overlooks the fact that the benefits of cryptocurrencies are unevenly distributed. A BIS report (2018: 93-97) indicates that the vast majority of cryptocurrency assets are concentrated in the hands of a small group of investors and institutions. As a result, instead of reducing inequality, we are seeing it deepen: global technological elites are gaining additional tools for capital accumulation, while peripheral users bear the speculative risk.

From the perspective of political philosophy, Rawls (1971: 75-83) emphasized that fair institutions must be designed in accordance with the difference principle—allowing inequalities only when they serve to improve the situation of the most vulnerable. Cryptocurrencies, if they act as a vehicle for speculation and wealth concentration, are contrary to this principle. Sen (1999: 26-29), in Development as Freedom, noted that true development consists in expanding the real possibilities of individuals. Cryptocurrencies can support development if they actually enable people to use new economic tools, rather than just creating narrow profit niches.

It is also worth recalling here the teaching of John Paul II in his encyclical Sollicitudo rei socialis (1987: §33-38), where he drew attention to the structural nature of social sin, manifested in the perpetuation of unjust economic mechanisms. Cryptocurrencies can become part of such a mechanism if, instead of inclusion, they create new forms of exclusion—e.g., through technological barriers, lack of digital education, or risks associated with cybercrime.

From the perspective of global inequalities, it is also important to note the differences in access to technology. While residents of Europe and North America use cryptocurrencies mainly as investment instruments, in Africa and Latin America they can serve as a substitute for unavailable banking services. Alvarez, Argente, and Van Patten (2022: 5-11), in their analysis of the case of El Salvador, which recognized Bitcoin as legal tender, point out that the effects of this experiment are ambivalent: on the one hand, it enabled some citizens to use modern tools, but on the other, it increased the risk of macroeconomic destabilization and dependence on volatile markets.

Finally, the issue of social justice in the world of cryptocurrencies should be seen in conjunction with environmental issues. The environmental costs of digital mining are borne primarily by local communities in countries with cheap energy, while the profits go to global investors. This transfer of costs to the most vulnerable violates the principle of solidarity and is an example of global injustice.

In summary, cryptocurrencies have the potential to promote social justice through financial inclusion, but in practice they often lead to greater inequality and exclusion. An ethical assessment of this phenomenon requires not only economic analysis, but also the inclusion of perspectives from political philosophy and social theology.

Religious and cultural interpretations of cryptocurrencies

The phenomenon of cryptocurrencies is not limited to the economic or technological dimension—it is also the subject of religious and cultural interpretations. In many circles, Bitcoin and other cryptocurrencies have gained an almost quasi-religious status, becoming a symbol of liberation from the power of state and banking institutions. These narratives create a kind of mythology of digital freedom, in which decentralization appears as a form of economic salvation.

Max Weber (1905/2011: 37–42) in The Protestant Ethic and the Spirit of Capitalism pointed out that economic practices are often rooted in deeper religious and ethical beliefs. In a similar way, the culture of cryptocurrencies refers to the ethos of independence, individual responsibility, and grassroots work. Some researchers interpret this culture as a new incarnation of the Protestant work ethic, adapted to the digital age.

From a Catholic perspective, cryptocurrencies are sometimes evaluated in the context of the Church's social teaching. Pope Francis' encyclical Laudato si' (2015: §129-134) emphasizes that the economy and technology must serve the integral development of the human person and not lead to exclusion and environmental degradation. Similarly, John Paul II in Sollicitudo rei socialis (1987: §33-36) warned against creating new forms of dependence and inequality. From this point of view, cryptocurrencies, if not oriented towards the common good, can be critically assessed as an element of an unjust global order.

In the tradition of liberation theology, represented by Gustavo Gutiérrez (1971/1988: 112-118), the economy should be a tool for the emancipation of the poor and marginalized. In this light, cryptocurrencies could serve as a tool for inclusion, as long as they are used in a communal and just manner. However, if they primarily serve the accumulation of capital by technological elites, they remain at odds with the message of solidarity and the preferential option for the poor.

From a cultural perspective, cryptocurrencies are becoming part of new forms of digital identity. Online communities are emerging that create their own rituals (e.g., HODL, to the moon), narratives, and symbols, and even treat the founder of Bitcoin, Satoshi Nakamoto, as an almost mythical figure. This sacralization of technology indicates that cryptocurrencies perform functions similar to those of civil religion: they organize the world of values, give meaning, and create community.

However, Morozov (2013: 127-131) warns against "technological solucionism"—the belief that every sphere of life can be saved by technological solutions. In this sense, treating cryptocurrencies as a remedy for all social ills may lead to the idolatry of technology, in which code replaces ethics and the market becomes a new idol.

In summary, religious and cultural interpretations of cryptocurrencies reveal that this phenomenon transcends economic and technical frameworks. Cryptocurrencies function as symbolic carriers of values and ideas that can be seen both as a path to freedom and justice and as new forms of idolatry. Their ethical assessment depends on whether they become rooted in traditions of caring for the common good and solidarity or remain a tool for deepening divisions.

Cryptocurrencies and individual freedom – the libertarian and community perspectives

The debate on cryptocurrencies essentially concerns two different concepts of freedom: individual freedom, emphasized in the libertarian tradition, and freedom rooted in the community, characteristic of republican and communitarian currents. Cryptocurrencies are often presented as a technology that liberates the individual from the domination of the state and banks, but their practical functioning shows that absolute autonomy is not possible without reference to the common good.

In the libertarian tradition, represented by Rothbard (1973: 41-47) and Nozick (1974: 149-153), freedom is equated with the absence of external coercion and full ownership rights to the fruits of one's labor and capital. Cryptocurrencies realize this vision by allowing individuals to freely trade financial resources outside the control of state institutions. Proponents of this perspective see blockchain as a tool of emancipation that allows for the construction of an economic system based on voluntary interactions and contracts, without the interference of central regulators.

However, Hannah Arendt (1958/2000: 144-148) emphasized in The Human Condition that freedom does not exist in isolation, but is realized in the space of common action. Similarly, MacIntyre (2007: 184-190) pointed out that true individual autonomy is only possible within the framework of community practices that shape virtues and values. Cryptocurrencies, if they become solely a tool for individual profit, threaten to degenerate freedom into anarchic selfishness. However, if they support cooperation and communal forms of exchange, they can become a means of achieving the common good.

Rawls (1971: 202-208) reminds us that individual freedoms must be linked to principles of social justice. In order to be ethically justified, financial freedom in the world of cryptocurrencies must be balanced by mechanisms to protect the weakest market participants. This means that although blockchain technology allows individuals to avoid traditional institutions, the political community has the right and obligation to create a regulatory framework that protects against exclusion, abuse, and destabilization of the system.

The libertarian perspective sees cryptocurrencies as a tool for complete individual sovereignty. The community perspective, on the other hand, reminds us that freedom without responsibility becomes an illusion. As Aristotle (2011: 112-114) wrote, true freedom lies in the ability to choose what is good in accordance with reason, not in the freedom to act arbitrarily. In this sense, cryptocurrencies require an ethic that can combine individual autonomy with concern for the community.

In summary, individual freedom in the world of cryptocurrencies must be considered in the tension between the libertarian idea of complete autonomy and the communitarian postulate of responsibility towards the community. Only then is it possible to build an ecosystem in which technology does not destroy social bonds, but strengthens them.

Cypherpunk, anarchism, and the political origins of cryptocurrencies

Cryptocurrencies have their roots not only in technological innovations, but also in a specific political and ideological vision. As early as the 1980s, David Chaum (1985: 1030-1034) pointed to the need for a payment system that would protect individual privacy from state and corporate interference. His concept of "electronic cash" was a response to the growing digitization of the economy and the associated risk of surveillance.

This gave rise to the cypherpunk movement, which developed in the 1990s and whose members—including Timothy C. May, Eric Hughes, and Hal Finney—saw cryptography as a tool for political emancipation. In the Crypto Anarchist Manifesto, May (1992) wrote that encryption would enable the creation of a new social order in which the state would lose control over the flow of information and capital. The guiding idea was the belief that technology could replace political institutions and that computer code could become a tool of freedom.

Maurer, Nelms, and Swartz (2013: 263-267) interpret Bitcoin as a social experiment in which technology not only enables transactions but also tests alternative models of power and community. In this sense, blockchain can be understood as a political project of decentralization—an attempt to transfer trust from the state and financial institutions to algorithms and peer-to-peer networks.

However, as Golumbia (2016: 41-45) notes, the cypherpunk and anarcho-capitalist narrative also carried risks. Under the guise of individual freedom, there is often extreme libertarianism, which rejects all community and social responsibility. In this view, cryptocurrencies become not so much a tool of emancipation as a means of dismantling institutions that support the common good.

Philosophically speaking, the cypherpunk movement was rooted in the tradition of anarchism and criticism of the state, but at the same time it reflected certain utopian hopes characteristic of technological modernism. Unlike classical anarchists, who advocated the construction of alternative social structures, cypherpunks believed that it was enough to change the communication and financial infrastructure to create a new political order.

In practice, Bitcoin and subsequent cryptocurrencies are the legacy of this ideology. Their designed anonymity, lack of a central administrator, and resistance to censorship are a conscious realization of the cypherpunk vision of "financial autonomy." At the same time, however, history shows that a complete escape from state institutions is impossible—cryptocurrencies remain entangled in the legal, economic, and social systems they seek to contest.

In summary, the political origins of cryptocurrencies lie in the ideas of digital anarchism and libertarianism. Understanding this genesis allows us to better assess their current functioning: as a technology that, on the one hand, promises freedom and decentralization, and on the other, raises questions about social responsibility and the limits of individual autonomy.

Cryptocurrencies, the labor market, and professional transformation

Blockchain technology and cryptocurrencies are having an increasing impact on the labor market, both structurally and ethically. Like previous technological revolutions, digital decentralization is leading to the emergence of new professions and employment models, but at the same time it is eliminating traditional forms of work, bringing with it the risk of marginalization of social groups that are not adapted to the changing economy.

According to a report by the World Economic Forum (2020: 14-19), the development of blockchain technology is conducive to the creation of new professional roles, such as network security analysts, smart contract developers, and regulatory compliance experts. At the same time, jobs related to cryptocurrency exchange operations, digital asset management, and legal advice on crypto assets are emerging. The future of the labor market is therefore shaping up to be one of technological specialization, requiring a high level of digital knowledge.

De Filippi and Wright (2018: 157-163) point out that blockchain enables the development of new models of professional collaboration, such as decentralized autonomous organizations (DAOs), which redefine the relationship between employer and employee. In such structures, decisions are made collectively by token holders, and traditional hierarchies are replaced by algorithmic rules. However, such organizations raise questions about accountability, fair distribution of profits, and the possibility of abuse of less privileged participants.

Kshetri (2021: 89-95) notes that blockchain can support transparency and sustainable development in supply chains, which affects working conditions in manufacturing sectors. By recording data on the production process, it becomes possible to monitor ethical standards, such as the prohibition of child labor and compliance with environmental standards. In this sense, the technology can promote labor justice and strengthen human rights.

At the same time, professional transformation poses serious challenges. Many traditional professions related to the banking, financial, and even accounting sectors may be reduced as a result of blockchain-based process automation. In this context, the ethical challenge is to ensure that technological changes do not lead to mass exclusion of workers, but are accompanied by reskilling and upskilling mechanisms. Sen (1999: 38-41) reminds us that development should consist in expanding the real opportunities of individuals, which in practice means the need to invest in education and the adaptation of employees to new conditions.

Tapscott and Tapscott (2016: 211-217) emphasize that blockchain opens up opportunities for a trust-based sharing economy in which workers can offer their services directly online, eliminating intermediaries. This type of model can increase professional autonomy, but at the same time exposes individuals to a lack of social protection and income instability. This raises the question of how to ensure a balance between professional freedom and community responsibility for job security.

In summary, cryptocurrencies and blockchain are changing the labor market on many levels—creating new opportunities but also generating new forms of risk. An ethical analysis of this process requires balancing the perspective of technological innovation with concern for workers' rights and social inclusion.

Culture of speculation and investor responsibility

One of the most controversial aspects of the cryptocurrency world is the phenomenon of speculation. The dynamic rises and falls in the value of Bitcoin or Ethereum attract millions of investors who treat the crypto market as a form of quick profit, often resembling financial gambling. In this context, the question arises about the ethical responsibility of the individual towards themselves, the economic community, and the global financial system.

Aristotle, in Nicomachean Ethics (2011: 47-51), pointed out that true virtue lies in the "golden mean" — between extravagance and greed. The speculative frenzy surrounding cryptocurrencies often goes beyond this measure, leading to irrational behavior on the part of investors who risk their entire fortune in the name of getting rich quick. Keynes (1936/2007: 158-162) described similar mechanisms, pointing to the "beauty contest" of financial markets, in which investors are guided not by the fundamental value of assets, but by their predictions of the moods of other market participants.

From the perspective of virtue ethics, MacIntyre (2007: 191-197) noted that economic practices should serve the internal goods of the community, not just the maximization of individual profit. Crypto speculation, based on short-term gains, separates finance from the real economy, becoming a practice devoid of virtue and destroying social trust.

Rawls' perspective also makes an important argument: if, as Rawls (1971: 243-250), justice is "the first virtue of social institutions," then investors should be aware that mass speculation destabilizing the market can hit the weakest participants in the economy, who bear the consequences of crises and inflation. The investor's responsibility therefore goes beyond his individual decisions – it also includes the consequences for the entire economic community.

In the Judeo-Christian tradition, the Bible repeatedly warns against greed and irresponsible accumulation of wealth. In the Gospel according to Luke (12:15), we read: "Be on your guard against all greed, because even when someone is rich, his life does not depend on his possessions." In relation to cryptocurrencies, these words remind us that speculation, if it becomes an obsession and detaches itself from the common good, threatens the moral integrity of the individual.

In summary, the culture of speculation in the world of cryptocurrencies reveals a tension between the individual's freedom to invest and their responsibility to the community. Investor ethics require not only economic rationality, but also an awareness that their decisions shape the structure of justice in the financial system.

The ethics of blockchain miners and developers

The cryptocurrency ecosystem relies on the work of two key groups: miners, who provide the network's computing power, and developers, who develop and maintain blockchain protocols. Both groups make a fundamental contribution to the functioning of the entire system, while also facing specific ethical challenges.

The work of cryptocurrency miners, especially in Proof-of-Work systems, is controversial due to its enormous energy and environmental costs. Research by Stoll, Klaassen, and Gallersdörfer (2019: 1647-1652) has shown that Bitcoin's carbon footprint is comparable to the greenhouse gas emissions generated by a medium-sized country. Similarly, de Vries (2022: 2168-2172) argues that the energy consumption of cryptocurrency networks is difficult to reconcile with the principles of sustainable development. The ethical question, then, is whether miners, profiting from mining, can ignore the environmental costs passed on to all of humanity.

From the perspective of Aristotle's classical virtue ethics (2011: 117-120), work should be directed toward the common good. If mining destroys the environment and threatens future generations, it is difficult to consider it ethically justified. MacIntyre (2007: 194-199) emphasized that human practices are morally valuable if they realize intrinsic goods and support the development of the community—in this sense, mining based solely on greed undermines its ethical meaning.

Blockchain developers, on the other hand, act as architects of a new financial system. Lawrence Lessig (1999: 6-12) pointed out that "code is law" – programmers' decisions are normative in nature, shaping the behavior of millions of users. The responsibility of developers is therefore not only to ensure the technical correctness of the code, but also to anticipate the social and economic consequences of their decisions. Fuller (1969: 39-42) noted that the morality of law requires clarity and predictability – the same criteria can be applied to blockchain code, which should be transparent and resistant to arbitrary manipulation.

It is worth emphasizing that programmers and miners are co-creators of the infrastructure on which user trust depends. If they neglect issues of security, transparency, or ecology, they undermine the foundations of the digital community. On the other hand, when they develop more sustainable mechanisms—such as Proof-of-Stake, promoted by Buterin (2022: 73-79)—they contribute to the ethical transformation of the entire system.

In summary, the work ethic of miners and blockchain developers requires a departure from a purely technical or economic perspective. Both groups should be aware that their actions have social, environmental, and normative dimensions. This responsibility includes both concern for the stability of the system and the common good of humanity.

User safety and the responsibility of exchanges

The issue of user security is one of the most serious ethical problems in the world of cryptocurrencies. Although blockchain technology itself provides a high level of transparency and resistance to manipulation, cryptocurrency exchanges, which act as intermediaries between the digital world and traditional finance, remain the weak point of the ecosystem. They are most often the target of hacker attacks, fraud, and abuse, which raises questions about the extent of their responsibility to investors.

Narayanan et al. (2016: 145-149) emphasize that one of the main problems with cryptocurrency exchanges is the lack of full transparency regarding reserves and security procedures. The collapse of the Mt. Gox exchange in 2014, which resulted in the disappearance of approximately 850,000 Bitcoins, became a symbol of the lack of adequate protective and regulatory mechanisms. This event showed that even the most decentralized technology does not eliminate risk if the intermediate points are managed irresponsibly.

Fuller (1969: 39-44) in The Morality of Law pointed out that in order to be moral, the law must ensure clarity and predictability of rules. Similarly, exchanges should implement transparent rules regarding data security, protection of funds, and procedures in the event of failures or intrusions. The absence of such standards constitutes a violation of basic institutional responsibility towards users.

Legal regulations play an important role in this context. Regulation (EU) 2023/1114 of the European Parliament and of the Council on markets in crypto-assets (MiCA) introduces a uniform legal framework for the entire European Union, imposing on exchanges the obligation of transparency, responsible management, and protection of customer interests. This document reflects Rawls' principle of justice (Rawls 1971: 211-216), according to which the freedoms of individuals must be protected by institutions that guarantee balance and security in the social system.

From an ethical point of view, exchanges act as trustees—their task is not only to enable trading, but also to ensure that market participants do not become victims of fraud or manipulation. If they ignore this requirement, they undermine the foundation of trust without which no economic community can function.

In summary, the responsibility of cryptocurrency exchanges has both a technical and a moral dimension. It includes the need for advanced security measures, financial transparency, and compliance with the legal framework. Otherwise, the financial freedom offered by cryptocurrencies is distorted by the risk of chaos and market anarchy.

Positive potential: financial inclusion and new models of cooperation

The debate on cryptocurrencies often emphasizes their negative aspects—speculation, crime, and environmental costs. However, their positive potential cannot be overlooked, which, from an ethical perspective, is linked to financial inclusion and the opening up of new forms of cooperation. Cryptocurrencies and blockchain technology can be a tool not only for capital accumulation, but also for expanding access to basic economic services and building more equitable social relations.

Prasad (2021: 215-222) points out that in many regions of the world, millions of people remain outside the traditional banking system due to a lack of infrastructure, identity documentation, or trust in institutions. Cryptocurrencies can give them access to digital payments, savings, and credit—all they need is a phone and an internet connection. In this sense, blockchain can become a tool for financial inclusion, fulfilling the demands for equality and economic justice.

De Filippi and Wright (2018: 205-210) emphasize that blockchain allows for the development of decentralized models of cooperation, in which traditional hierarchies are replaced by networks of mutual trust. Examples include digital cooperatives and peer-to-peer platforms, which enable joint resource management and profit sharing. In such structures, code replaces arbitrary decisions by institutions, which promotes transparency and participation.

Allen (2022: 142-148) notes that fintech and cryptocurrencies can promote greater financial stability if they are used to create solutions that support micro-entrepreneurship. In practice, this means that small entrepreneurs in developing countries can gain access to financial tools that were previously reserved for large corporations.

The philosophical perspective of Amartya Sen (1999: 27-31) reminds us that development is primarily about expanding human capabilities and freedoms. Cryptocurrencies, if they support the ability of individuals to participate in the economy and society, fulfill an emancipatory function. They can therefore become a tool of solidarity—provided that they are not subordinated solely to the logic of profit maximization.

In practice, examples of the use of blockchain in humanitarian projects, e.g., for the distribution of aid in refugee camps, show that this technology can support those most in need by ensuring the transparency and security of transfers (WEF 2020: 31-35). Thus, cryptocurrencies and blockchain, although often associated with elite speculation, can serve as a tool for social justice under the right conditions.

In summary, the positive potential of cryptocurrencies lies in their ability to overcome financial exclusion and build new models of cooperation. The ethical challenge remains whether the global community will be able to use these opportunities for the common good, or whether they will be appropriated by a few interest groups.

Future scenarios: financial utopia or dystopia?

The development of cryptocurrencies opens up extremely broad prospects for the world of finance, but at the same time raises questions about whether the future will take the form of a utopia of money democratization or rather a dystopia of chaos and exclusion. These scenarios are not purely theoretical—we are already seeing trends that could point in both directions.

On the one hand, enthusiasts of blockchain technology emphasize its potential to create a more equitable, transparent, and fraud-resistant financial system. De Filippi and Wright (2018: 221-227) point out that decentralization makes it possible to limit the power of central institutions and create space for innovation and economic self-governance. In such a scenario, cryptocurrencies could implement Rawls' principle of equal opportunity (Rawls 1971: 65-73), offering access to financial tools regardless of place of birth or social status.

However, critics warn against the opposite scenario. Golumbia (2016: 53-57) notes that instead of democratization, the cryptocurrency movement may lead to the concentration of capital and the strengthening of extremely libertarian ideas that reject institutions of the common good. In this view, cryptocurrencies could become a tool for new technological oligarchies, reproducing inequalities and weakening states.

The environmental issue is also significant. Stoll, Klaaßen, and Gallersdörfer (2019: 1655-1660) point out that intensive cryptocurrency mining may destabilize global efforts to reduce CO_2 emissions in the long term. De Vries (2022: 2175-2180) emphasizes that if sustainable mechanisms are not introduced, cryptocurrencies may become a symbol of financial dystopia—a technology that contributes to ecological disaster.

Sen (1999: 88-92) reminds us that true development consists in expanding human freedom and capabilities. The utopian scenario therefore assumes that cryptocurrencies will support the emancipation of individuals, the development of micro-entrepreneurship, and financial inclusion. The dystopian scenario, on the other hand, is associated with deepening inequality, financial anarchy, and environmental degradation.

The ethical question about the future of cryptocurrencies therefore concerns the social and institutional framework that will be given to them. Morozov (2013: 131-135) warns against the illusion of technological solutionism, which assumes that technology alone will solve social problems. The future of cryptocurrencies does not depend solely on algorithms, but on the ethical and political choices of the communities that shape them.

In summary, the future of cryptocurrencies lies somewhere between utopia and dystopia. They can become a tool for global justice and solidarity, but they can just as easily become a source of new forms of domination and crises. Resolving this tension will depend on the ethical responsibility of both the creators of the technology and political institutions, as well as the users themselves.

Synthesis of issues and ethical recommendations

An analysis of the ethical dimensions of cryptocurrencies shows that this phenomenon is multidimensional and its assessment depends on the philosophical, economic, and social perspective adopted. Cryptocurrencies carry enormous potential for financial freedom and innovation, but at the same time they give rise to risks related to inequality, speculation, crime, and environmental degradation.

A synthesis of the above considerations leads to several key issues:

1. *The tension between freedom and responsibility* – the libertarian tradition (Rothbard 1973; Nozick 1974) sees cryptocurrencies as a tool for absolute individual autonomy, while the communitarian perspective (Arendt 2000; MacIntyre 2007) reminds us that

freedom must be linked to the common good. An ethical assessment of cryptocurrencies requires finding a balance between these two visions.

2. *Issues of social* justice—as Rawls (1971: 75-83) notes, institutions must be designed to improve the situation of the weakest. Current cryptocurrency practices often exacerbate inequalities, but there is potential for financial inclusion (Prasad 2021; Sen 1999) if appropriate support mechanisms are implemented.
3. *Environment and sustainability* – research on Bitcoin's carbon footprint (Stoll, Klaaßen & Gallersdörfer 2019; de Vries 2022) shows that this technology requires an ethical transformation towards more environmentally friendly solutions, such as Proof-of-Stake (Buterin 2022).
4. *Security and regulation* – cases of cryptocurrency exchange collapses indicate that financial freedom cannot exist without a responsible institutional framework. Regulations such as MiCA (2023) are an attempt to respond to this challenge.
5. *Culture of speculation* – virtue ethics (Aristotle 2011; MacIntyre 2007) and biblical teaching (Luke 12:15) warn against greed and intemperance, which can lead to economic destabilization and the destruction of social bonds.

In light of these problems, several **ethical recommendations** can be proposed:

- *The principle of balance:* cryptocurrencies should be developed in a way that combines individual freedom with concern for the common good, avoiding the extremes of libertarianism and statism.
- *The principle of inclusion:* the priority should be to combat financial exclusion through projects that support access to blockchain technology for the poorest.
- *The principle of environmental responsibility:* any development of cryptocurrencies should take into account their environmental impact, promoting energy-efficient models and renewable energy sources.
- *The principle of transparency and trust:* exchanges and intermediaries must operate in accordance with the highest ethical and legal standards, ensuring the protection of users.

- *The principle of virtue and moderation:* investors should be aware that financial speculation is not an end in itself, and that an ethical attitude requires responsibility towards the community.

In summary, cryptocurrency ethics requires an interdisciplinary approach that combines philosophical reflection, legal regulations, and economic practice. The future of cryptocurrencies depends not only on technological development, but above all on the ethical choices of individuals, communities, and institutions that shape this new financial world.

Conclusion

Towards the ethics of responsible freedom in the world of cryptocurrencies

The analysis carried out in this article shows that cryptocurrencies are one of the most complex phenomena of our time, combining technological innovation, economic dynamics, social tensions, and philosophical questions. Their significance lies not only in their function as an alternative means of payment, but above all in the fact that they are becoming a symbol of disputes over freedom, justice, and responsibility in the global order.

On the one hand, cryptocurrencies realize the ideal of financial freedom: they enable individuals to become independent of central banks, open up access to economic services for excluded people, and foster new models of cooperation based on trust. In this sense, they can be seen as a tool for emancipation which, according to Amartya Sen's intuition (1999: 27-31), expands the real capacity of individuals to participate in economic and social life.

On the other hand, however, the practice of cryptocurrencies reveals the dark side of technology: speculation, concentration of wealth, use for criminal activities, and above all, enormous environmental costs. In Rawlsian terms (1971: 75-83), such inequalities and threats undermine the principle of social justice, and from an ecological perspective – as Francis reminds us in Laudato si' (2015: §129-134) – they become a manifestation of a lack of care for the common home of humanity.

In the face of these tensions, it is necessary to formulate an ethic of responsible freedom. It is based on four principles:

1. *Freedom rooted in the common good* – individual autonomy in the use of cryptocurrencies must be linked to concern for stability and community justice.
2. *Financial inclusion as a priority* – cryptocurrencies should serve to expand access to financial services, especially in excluded regions.
3. *Sustainable development and ecology* – blockchain technologies must be developed in accordance with the principles of environmental responsibility, eliminating excessively energy-intensive models.
4. *Transparency and institutional trust* – exchanges and intermediaries must operate in accordance with the principles of legal ethics (Fuller 1969: 39-44), ensuring the safety of users.

The conclusion of this study is therefore twofold. First, cryptocurrencies are neither inherently good nor bad – their ethical assessment depends on how they are used and regulated. Second, the future of cryptocurrencies will depend not so much on the technology itself as on the ethical and political wisdom of the communities that will define the framework for its operation.

As MacIntyre (2007: 263-267) wrote, ethics cannot be limited to technical calculations, but must be based on a common search for the good. If cryptocurrencies become part of such a practice, they can contribute to building a more just and solidarity-based world. However, if they are appropriated by the logic of greed and anarchy, they may prove to be one of the most serious threats to social and ecological stability in the 21st century.

References

Floridi, L., & Chiariatti, M. (2020). GPT-3: Its Nature, Scope, Limits, and Consequences. *Minds & Machines, 30*, 681–694.

Geiger, C. (2021). The Missing Goal-Scorers in the Artificial Intelligence Team: Of Big Data, the Fundamental Right to Research and the Failed Text and Data Mining Limitations in the CDSM Directive. *Intellectual Property and Sports: Essays in Honor of P. Bernt Hugenholtz, Kluwer Law International*, 383–394.

Geiger, C., & Iaia, V. (2024). The Forgotten Creator: Towards a Statutory Remuneration Right for Machine Learning of Generative AI. *Computer Law & Security Review, 52*, 1–9.

Geiger, C., Frosio, G., & Bulayenko, O. (2018). Crafting a Text and Data Mining Exception for Machine Learning and Big Data. *Intellectual Property and Digital Trade, Geneva/Strasbourg*, 95–112.

Geiger, C., Frosio, G., & Bulayenko, O. (2018). Text and Data Mining in the Proposed Copyright Reform. *International Review of Intellectual Property and Competition Law, 49*, 814–844.

Hugenholtz, P. B. (2012). The Story of the Tape Recorder and the History of Copyright Levies. *Copyright and the Challenge of the New, Wolters Kluwer*.

Lemley, M. (2024). How Generative AI Turns Copyright Upside Down. *Columbia Science & Technology Law Review, 25*(2), 190–212.

Lucchi, N. (2023). ChatGPT: A Case Study on Copyright Challenges for Generative AI Systems. *European Journal of Risk Regulation, 15*(3), 602–624.

Margoni, T., & Kretschmer, M. (2022). A Deeper Look Into EU TDM Exceptions. *GRUR International, 71*, 685–701.

Netanel, N. (2003). Impose a Noncommercial Use Levy to Allow Free Peer-to-Peer Sharing. *Harvard Journal of Law & Technology, 17*(1), 2–83.

Oksanen, V., & Välimäki, M. (2005). Copyright Levies as an Alternative Compensation Method. *Review of Economic Research on Copyright Issues, 2*(2), 25–39.

Senftleben, M., Margoni, T., et al. (2022). Ensuring Visibility and Accessibility of European Creative Content. *JIPITEC, 13*, 67–86.

Truyens, M., & Van Eecke, P. (2014). Legal Aspects of Text Mining. *Computer Law & Security Review, 30*, 153–170.

Wang, J. T., Deng, Z., et al. (2024). An Economic Solution to Copyright Challenges of Generative AI. *arXiv*.

Contact address of the authors:

Prof. dr hab. Wojciech Slomski, Institute of Technology and Business in Prešov, Faculty of Economics, Management and Marketing, Masarykova 22, 080 01 Prešov, Slovak Republik, e-mail: slomski@autograg.pl

Demographic policy in conditions of depopulation (the example of Poland)

Zdzisław Sirojć[1]

[1]Wyższa Szkoła Kształcenia Zawodowego

Abstract

This article provides a comprehensive analysis of Poland's demographic policy in the context of growing depopulation, combining normative frameworks (ICPD, EU Charter of Fundamental Rights, Polish Constitution) with cross-country comparisons (Czech Republic, Germany, Spain) and conclusions from demographic literature. It has been shown that cash transfers, although they reduce child poverty, do not permanently change fertility trajectories if they are not intertwined with "everyday institutions": a dense and accessible ECEC network, housing availability, gender equality in the labor market, and employment stability. The mechanism of the "delay loop" of first birth has been identified as the main channel reducing the period and cohort TFR, reinforced by housing shortages and instability in early careers. The role of migration as a buffer and catalyst was also highlighted, provided that real integration (language, validation of qualifications, housing) is achieved. A portfolio of reforms was proposed: recalibration of benefits (support for the first child), treating ECEC as work infrastructure, a "use-it-or-lose-it" component in parental leave for fathers, housing policy (social rental and fixed-rate loans), public funding of ART as an element of public health, and an "anchor" in parental leave for fathers.-it" component in parental leave for fathers, housing policy (social rental and fixed-rate loans), public funding of ART as an element of public health, and a "demographic anchor" in the budget with cyclical evaluation (every 24 months). The conclusion is that an effective demographic policy is a development strategy—a restructuring of everyday institutions—rather than transfer arithmetic; sustainable fertility is inseparable from an egalitarian organization of the life cycle.

Keywords: Demographic policy, fertility, ECEC (nurseries and kindergartens), housing, gender equality, labor market, migration and integration, in vitro/ART, reproductive health, depopulation, aging population, governance and evaluation.

Introduction

The starting point is the thesis that Poland has entered a period of sustained accumulation of unfavorable demographic phenomena: a declining birth rate, a rapid decline in the number of women of childbearing age, continuing net emigration of selected cohorts of young adults, a paradoxical increase in mortality in some age groups in the last decade, and accelerated population aging. In pessimistic scenarios discussed in the literature and strategic documents, the population of Poland could fall well below 30 million by the end of the 21st century; in extreme scenarios—with persistently low fertility and a weak migration balance—it could even fall to around a dozen million. This projection should be compared with global population growth and the fact that some Western European countries maintain higher fertility rates and are clearly more attractive to migrants. The risk vector resulting from this asymmetry is threefold: (1) economic – labor shortages and wage and inflationary pressure weakening competitiveness; (2) fiscal – growing pension, health, and care burdens; (3) territorial – polarization of development and depopulation of medium-sized cities and peripheral areas (GUS 2023; GUS 2024). In this chapter, I organize the concepts and models of demographic policy, reconstruct the channels of state influence, place the case of Poland in comparison (Czech Republic, Germany, Spain), and propose a strategic framework (goals–instruments–evaluation), consistently based on the normative anchors of international and EU law, in which demography is linked to well-being, family rights, and equality—not to the arithmetic of "numbers for numbers' sake."

Normative anchors: well-being, family rights, and state obligations

For thirty years, the modern approach to population policies has adhered to the principle that the well-being of individuals and families is at its core. The Programme of Action adopted at the ICPD conference in Cairo puts it bluntly: “The aim of population-related policies and programs is to enhance individual well-being and quality of life” (United Nations 1995: 19). The chapter on reproductive health goes on to say: "Reproductive health... implies that people... have the capability to reproduce and the freedom to decide if, when and how often to do so" (United Nations 1995: 40). In EU law, this idea is reinforced by Article 33 of the

Charter of Fundamental Rights: "The family shall enjoy legal, economic and social protection" (European Union 2012: 58). In the Polish constitutional order, this is equally clear: "The state shall take into account the welfare of the family in its social and economic policy" (Constitution of the Republic of Poland 1997, Article 71(1)). These three anchors – Cairo, EU, and constitutional – form the framework for further consideration: demographic policy is not intended to “produce births” but to remove barriers and reduce the risks associated with procreative decisions so that declared preferences can materialize (Okólski 2005: 15–35; Okólski and Fihel 2012: 11–40).

Models and mechanisms: from pronatalism to the “institutions of everyday life”

Classic approaches differentiate between pro-natalist (encouraging births), anti-natalist (discouraging births; historically – China's one-child policy) and neutral models; in practice, countries use mixed configurations, shifting emphasis depending on the economic situation, demographics and political culture (Mitręga 1995; Mitręga 2000). In the last two decades, however, the paradigm has shifted from simple cash transfers to everyday institutions – those that determine the compatibility of work and parenthood (time, income, career risk). Gøsta Esping-Andersen, analyzing the "incomplete revolution" of gender roles, notes: "a sustainable fertility level is inseparable from an egalitarian organization of the life course" (Esping-Andersen 2009: 5; cf. 183–236). Ron Lesthaeghe, in his classic synthesis of the "second demographic transition," recalls the tempo effect: delaying the first birth lowers the periodic TFR and masks the potential of cohorts; hence the need for cohort approaches and caution regarding short-term fluctuations (Lesthaeghe 2010: 217–256). The technical basis for this caution was explained by John Bongaarts and Griffith Feeney (1998: 271–291), who showed how shifts in the age of mothers at birth distort the TFR and why financial transfers alone generate short “bulges” without changing the generational trajectory. The conclusion is clear: cash benefits are necessary but insufficient; the direction of the trend is determined by care and education services, the labor market, housing, and gender equality (McDonald 2000: 427–440).

Channels of state influence: direct and indirect (structural)

From the point of view of causal mechanics, we can distinguish between direct and indirect interventions. The former include benefits and tax breaks (including components that encourage first births at a younger age), housing vouchers and subsidies, as well as public funding for infertility diagnosis and treatment, including assisted reproductive technology (ART) procedures. Indirect interventions create the infrastructure of everyday life: a dense and affordable network of early childhood education and care (ECEC), flexibility of working hours and location, job stability, enforced equal pay and reduction of the "motherhood penalty," housing availability (social rental and predictable credit), and a predictable tax and contribution system. Cross-country comparisons and meta-analyses indicate that it is the second group—by lowering the opportunity costs of parenthood and reducing career risks, especially for women—that has a lasting impact on period and cohort fertility (Esping-Andersen 2009: 87–136; McDonald 2000: 427–440). At the micro level, housing is particularly important: the transition to parenthood is strongly associated with obtaining adequate housing, and housing regimes can either support or suppress fertility (Mulder and Wagner 2001: European Journal of Population 17(2), 147–174; Billari and Kohler 2004: Population Studies 58(2), 161–176).

Polish diagnosis: the delay loop, the housing gap, and fiscal rigidities

Polish practice over the last decade has highlighted the limitations of transfer-focused policies. Income programs have effectively reduced child poverty, but their impact on births has been short-lived and insufficient to reverse the trend. The reason is structural: the weakness of ECEC, high housing costs in metropolitan areas, and job instability in the early stages of a career create a "delay loop" for the first birth; without the first, even generous incentives for subsequent births will not work (Esping-Andersen 2009: 137– 182; Lesthaeghe 2010). At the same time, the size of the 20–34 cohorts is shrinking and the working-age population is declining; the old-age dependency ratio (OADR) is rising, increasing pressure on pension, health, and care benefits (GUS 2023: 33–71; GUS 2024: 29–66). Łódź is emblematic: since the 1980s, it has lost over 200,000 inhabitants; the decline in demographic status, a thinner tax base, and rising unit costs of public services are creating a depopulation spiral that cannot be broken by ad hoc redistribution without investment in ECEC, housing, transport, and quality of life (Okólski and Fihel 2012: 263–298). "Geography" here is economics: fewer residents means a smaller fixed cost base, making it more difficult to maintain service standards and reducing the attractiveness of the area for settlement.

Comparisons: Czech Republic, Germany, Spain — mechanisms, not carbon copies

The Czech Republic is a study in the coherence of instruments. After fertility collapsed in the 1990s to "below replacement" levels, the state combined the expansion of tax breaks and benefits with the rapid development of ECEC, flexible forms of employment for women, housing packages, and widespread availability of ART. The effect was gradual: an increase in the TFR over two consecutive decades and better implementation of procreative plans despite a shift in the age of the first child (Sobotka 2011: 241–260; synthesis in: Okólski and Fihel 2012: 201–234).

After a long period of fluctuation, Germany reformed ECEC, introduced non-transferable paternity components to parental leave (the use-it-or-lose-it principle) and institutionalized the recognition of immigrants' qualifications; this translated, with a delay, into a higher period TFR and better integration indicators (Castles, de Haas, and Miller 2020: 193–244; Lesthaeghe 2010).

Spain, a classic case of long-term low fertility, combined labor market and housing reforms with the selective opening of migration channels to alleviate labor supply shortages and raise household incomes (Castles, de Haas, and Miller 2020: 245–262).

The common denominator: where the cost of everyday family life was reduced (ECEC, housing, gender equality, migration integration), fertility stabilized at a higher level than where cash transfers predominated.

Migration as a shock absorber and catalyst — condition: integration, not just residence

Migration does not "solve demographics," but it buys time and mitigates the effects of aging if the influx is accompanied by integration: intensive language learning, rapid validation of qualifications, clear paths to permanent residence, and housing policies to avoid pushing families to the periphery. Migration regimes differ in philosophy (liberal, employment-based, assimilationist, multicultural), but in practice they are mixtures and segmented — from student pathways, through visas for highly skilled workers, to fast-track pathways in shortage occupations (Castles, de Haas, and Miller 2020: 1–31; 245–262). In the Polish context, the influx of Ukrainian citizens after 2014/2022 increased the supply of labor and demand, but the lasting effect depends on the transition from the status of a “guest” to the role of a neighbor-taxpayer: school, language, profession, housing. The German experience shows that proceduralization of qualification recognition and cooperation with local governments are prerequisites for avoiding the “import of precariat” and permanent labor market segmentation (Castles, de Haas, and Miller 2020: 193–244).

Reproductive health and ART: patient rights, public health, demography

The WHO classifies infertility as a disease; public policy that treats ART as an integral part of the health system fulfills both a human rights obligation and the demographic goal of the . The international standard—the above-quoted excerpt from the Cairo Programme of Action—is unambiguous: it is about the ability and freedom to make reproductive decisions, and thus about living conditions and access to services (United Nations 1995: 40). Demographic literature indicates that the availability and destigmatization of ART significantly increase the finite (cohort) probability of parenthood among couples affected by infertility; the proportion of births thanks to ART is growing in a number of European countries (Zegers-Hochschild et al. 2017: 1786–1801). From a public policy perspective, ART is therefore three things at once: a patient's right, a public health service, and a pro-population tool—but it remains part of a larger puzzle (housing, ECEC, labor market).

Reform program: portfolio of instruments, sequence, and indicators

Family income. Shift the burden from universal transfers with diminishing marginal effectiveness to a progressive mix of targeted benefits and allowances (especially support for the first child at a younger age), with automatic indexation to inflation (Esping-Andersen 2009: 137–182).

ECEC as work infrastructure. A dense, inexpensive, and high-quality network of nurseries/kindergartens with long hours – the cheapest “golden mean” of fertility compatible with employment (Esping-Andersen 2009: 183–236).

The labor market and gender equality. Enforced equal pay, leave with a non-transferable paternal component (use-it-or-lose-it), the right to flexible work arrangements without "maternity penalties" and "career penalties"; according to the "gender equity and fertility" hypothesis, without closing the equality gap in the private and public spheres, fertility will not return to replacement levels (McDonald 2000: 427–440).

Housing. Fixed-rate start-up loans for young households, expansion of the social rental segment, and rent subsidies in metropolitan areas; housing availability is one of the primary constraints on first-time childbirth (Mulder and Wagner 2001; Billari and Kohler 2004). Reproductive health. Public funding for in vitro fertilization and infertility treatment, preconception care, health education, and psychological support (Zegers-Hochschild et al. 2017; Okólski and Fihel 2012: 145–175).

Migration. Profiled channels (students, high qualifications, shortage occupations), rapid validation of qualifications, intensive language learning, permanent residence pathways correlated with housing policy (Castles, de Haas, and Miller 2020: 193–262). Silver economy. Treating aging as a source of demand and employment (long-term care, health, assistive technologies, housing with services).

Governance and evaluation. A "demographic anchor" in the budget, a central analytical center, and a set of indicators: periodic and cohort TFR, final childlessness, age at birth of first child, ECEC coverage and hourly availability, wage gap and "maternity penalty," housing availability indicators, migration balance, OADR/POADR, healthy life years (HLY). Reviews every 24 months and a correction mechanism (GUS 2023; GUS 2024; cf. comparative approaches in: Castles, de Haas, and Miller 2020).

The sequence should start with investments with the highest social return: ECEC + housing + recognition of qualifications and language for migrants, in parallel – legal framework and financing of ART; then – a full package of gender equality in the labor market. The implementation risks are: fiscal short-sightedness (preference for transfers over services), ministerial fragmentation, territorial asymmetries (metropolises vs. peripheries), and cultural polarization (disputes over ART and reproductive education). Each of these can be mitigated if demographic policy is a state strategy with a clear mandate, timetable, and evaluation mechanism.

Conclusion

A development strategy, not arithmetic

Demographic policy in the context of Polish depopulation must be a development policy: a restructuring of everyday institutions, from nurseries to housing, and from the labor market to fertility clinics. Its goal is to rebuild the living conditions of those who want to have children and to manage age-related change while minimizing fiscal and social risks. If, following Esping-Andersen, "sustainable fertility is inseparable from the egalitarian organization of the life cycle" (2009: 5), then the draft Polish demographic strategy becomes a test of our ability to modernize not through ad hoc redistribution, but through a permanent reduction in the opportunity costs of parenthood and an increase in the predictability of family life.

References

Billari, F. C., & Kohler, H. P. (2004). Patterns of Low and Lowest-Low Fertility in Europe. *Population Studies, 58*(2), 161–176.

Bongaarts, J., & Feeney, G. (1998). On the Quantum and Tempo of Fertility. *Population and Development Review, 24*(2), 271–291.

Castles, S., De Haas, H., & Miller, M. J. (2020). The Age of Migration: International Population Movements in the Modern World. *Polity Press*.

Central Statistical Office. (2023). Demographic Yearbook 2023. *GUS*.

Central Statistical Office. (2024). Demographic Yearbook 2024. *GUS*.

Constitution of the Republic of Poland. (1997). *Warsaw: Sejm Publishing House*.

Esping-Andersen, G. (2009). The Incomplete Revolution: Adapting to Women's New Roles. *Polity Press*.

European Union. (2012). Charter of Fundamental Rights of the European Union. *Luxembourg: Publications Office of the European Union*.

Lesthaeghe, R. (2010). The Unfolding Story of the Second Demographic Transition. *Population and Development Review, 36*(2), 211–251.

McDonald, P. (2000). Gender Equity in Theories of Fertility Transition. *Population and Development Review, 26*(3), 427–439.

Mulder, C. H., & Wagner, M. (2001). The Connections Between Family Formation and First-Time Home Ownership in the Context of West Germany and the Netherlands. *European Journal of Population, 17*(2), 147–174.

Okólski, M. (2005). Demography: Basic Concepts, Processes, and Theories in an Encyclopedic Overview. *Scholar Publishing House*.

Okólski, M., & Fihel, A. (2012). Demography: Contemporary Phenomena and Theories. *Scholar Publishing House*.

Sobotka, T. (2011). Fertility in Central and Eastern Europe After 1989: Collapse and Gradual Recovery? *Journal of Population Research, 28*(3), 241–260.

United Nations. (1995). Report of the International Conference on Population and Development. Programme of Action (Cairo, September 5–13, 1994). *New York: United Nations*.

Zegers-Hochschild, F., Adamson, G. D., De Mouzon, J., et al. (2017). International Glossary on Infertility and Fertility Care, 2017. *Human Reproduction, 32*(9), 1786–1801.

Contact address of the author:

Prof. Zdzisław Sirojć, Wyższa Szkoła Kształcenia Zawodowego, plac Powstańców Śląskich 1, 53-329 Wrocław, siro19@wp.pl

REVIEW STUDY

Problems of Knowledge Society in the Light of Philosophy

Anna Wawrzonkiewicz-Slomska[1]

[1] Institute of Technology and Business in Prešov, Faculty of Economics, Management and Marketing

Ambrozy, Marián; Hvizdová, Eva. Selected Problems of Knowledge Society in the Light of Philosophy. Nova Science Publishers, Inc., 2025. ISBN 979-8-89530-883-7.

The volume *Selected Problems of Knowledge Society in the Light of Philosophy* by Marián Ambrozy and Eva Hvizdová stands as an exceptionally accomplished scholarly work whose intellectual ambition, conceptual depth, and interdisciplinary coherence place it among the most valuable contemporary contributions to the study of the knowledge society. While formally situated within philosophical inquiry, the book achieves a level of analytical sophistication that makes it profoundly relevant to economics, political economy, and theories of development. Its central achievement lies in articulating a vision of knowledge as the decisive economic resource of modern civilization—one that transcends narrow quantitative models and restores normative depth to economic analysis.

From the standpoint of economics, the monograph offers a decisive advance beyond instrumental and technocratic interpretations of the knowledge economy. Ambrozy and Hvizdová persuasively demonstrate that knowledge cannot be reduced to human capital indicators, innovation indices, or productivity metrics without losing its structural and generative significance. Instead, they present knowledge as an embedded economic force, inseparable from institutional stability, cultural meaning, ethical orientation, and educational continuity. This perspective represents a major theoretical enrichment of contemporary economic discourse, particularly in an era dominated by short-term efficiency and technocratic governance.

The authors' analysis provides an intellectually compelling foundation for rethinking economic growth in qualitative rather than merely quantitative terms. By emphasizing the formative role of education, intellectual autonomy, and reflective capacity, the book situates economic development within a broader civilizational horizon. Education emerges not simply as a tool for labor-market adaptation, but as the principal mechanism through which societies cultivate innovation, resilience, and long-term competitiveness. In this sense, the monograph offers one of the most coherent theoretical justifications for sustained public investment in education and research currently available in the literature on the knowledge economy.

From a political economy perspective, the work is particularly distinguished by its clarity regarding the relationship between knowledge, power, and institutional order. Ambrozy and Hvizdová convincingly argue that markets alone cannot secure the conditions necessary for the reproduction of knowledge-intensive economies. Stable normative frameworks, long-term policy vision, and institutional trust are shown to be indispensable prerequisites for economic systems based on creativity and innovation. This insight constitutes a powerful corrective to reductionist market-centric models and provides a philosophically grounded defense of the strategic role of the state in knowledge-based development.

The global orientation of the book further enhances its scholarly significance. Rather than confining their analysis to a specific regional or national experience, the authors engage with the knowledge society as a universal structural transformation affecting diverse economic systems. This makes the monograph highly relevant to both advanced economies seeking to sustain innovation and emerging economies aiming to leapfrog developmental stages through strategic investment in knowledge and education. The dialogical inclusion of responses from prominent scholars deepens the analytical texture of the book and underscores its international intellectual reach.

Methodologically, the work is exemplary. The authors demonstrate exceptional conceptual discipline, integrating philosophical reasoning with economic insight in a manner that is both rigorous and accessible. The text avoids speculative abstraction while maintaining a level of theoretical refinement rarely achieved in interdisciplinary studies. As a result, the monograph succeeds in bridging the gap between normative theory and economic analysis, offering a framework that is as intellectually persuasive as it is analytically robust.

In sum, *Selected Problems of Knowledge Society in the Light of Philosophy* is a truly distinguished scholarly achievement. It redefines the economic meaning of knowledge with rare clarity and depth, offering a vision of development grounded in intellectual integrity, institutional responsibility, and long-term societal flourishing. The book deserves to be recognized as a major contribution to contemporary debates on the knowledge economy and stands as an essential reference for economists, political theorists, policymakers, and scholars concerned with the future of development in a globalized world.

Contact address of the author:

Anna Wawrzonkiewicz-Slomska, Institute of Technology and Business in Prešov, Faculty of Economics, Management and Marketing, Masarykova 22, 080 01 Prešov, Slovak Republik, e-mail: wawrzonkiewicz@vste.sk