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ECONOMETRIC MODELING OF MACROECONOMIC INTERRELATIONS: A SIMULTANEOUS APPROACH TO GDP, CONSUMER SPENDING, AND CAPITAL ACCUMULATION ANALYSIS

ЕКОНОМЕТРИЧНЕ МОДЕЛЮВАННЯ МАКРОЕКОНОМІЧНИХ ВЗАЄМОЗВ'ЯЗКІВ: СИМУЛЬТАТИВНИЙ ПІДХІД ДО АНАЛІЗУ ВВП, СПОЖИВЧИХ ВИТРАТ ТА НАГРОМАДЖЕННЯ КАПІТАЛУ

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The article is dedicated to the development and testing of a simultaneous econometric model describing the interrelations between key macroeconomic indicators: gross domestic product, final consumption expenditure, and gross capital formation. For parameter estimation, the two-stage least squares method was applied. The empirical base includes data from 2000 to 2021. The structural form of the model consists of three equations: consumption function, investment function, and GDP formation function. Average monthly wages and gross savings were utilized as exogenous variables. Results demonstrate a high level of explanation for endogenous variable variation: the coefficient of determination for the consumption equation is 0.996, investment equation – 0.937, GDP equation – 0.996. The F-test confirmed the adequacy of all three model equations. The system of econometric equations reveals stable structural interdependencies between key macroeconomic indicators, where final consumption expenditure acts as the primary driver of GDP formation.

Keywords: simultaneous model, econometric analysis, GDP, consumer spending, gross capital formation, macroeconomic forecasting, model, economic growth, macroeconomic dynamics.

Стаття присвячена розробленню та апробації симультативної економетричної моделі, що описує взаємозв'язки між ключовими макроекономічними показниками України у динаміці: валовим внутрішнім продуктом, кінцевими споживчими витратами та валовим нагромадженням капіталу. Для оцінювання параметрів застосовано двокроковий метод найменших квадратів. Емпірична база включає макроекономічні статистичні дані України за 2000-2021 рр. Структурна форма моделі складається з трьох рівнянь: функції споживання, інвестиційної функції та функції формування ВВП. У якості екзогенних змінних використано

середньомісячну заробітну плату та валове заощадження. Проведено перевірку умов ідентифікації моделі за допомогою обов'язкової умови порядку та рангової умови, що підтвердило точну ототожненість усіх рівнянь системи. Встановлено систему параметричних взаємозв'язків між коефіцієнтами структурної та скороченої форм. Результати показують високий рівень пояснення варіації ендогенних змінних: коефіцієнт детермінації для рівняння споживання становить 0,996, інвестиційного рівняння – 0,937, рівняння ВВП – 0,996. Статистична перевірка за критерієм Стьюдента виявила, що найбільш значущий зв'язки між ВВП та споживчими витратами, а також між валовим заощадженням та капіталонагромадженням. F-тест підтвердив адекватність усіх трьох рівнянь моделі. Виявлений значний позитивний вплив середньомісячної заробітної плати на рівень споживання підтверджує домінуючу роль доходів домогосподарств у стимулюванні сукупного попиту, тоді як пряма залежність валового нагромадження капіталу від обсягу заощаджень свідчить про ефективний функціональний механізм внутрішнього інвестування. Крім того, наявність зворотних зв'язків між ендогенними змінними підкреслює мультиплікативний характер зростання ВВП, за якого кожна одиниця приросту нагромадження капіталу генерує додатковий споживчий попит, що інтегрально відображено в останньому рівнянні моделі. Незначний негативний вплив споживання на темпи нагромадження капіталу може вказувати на певний дефіцит інвестиційних ресурсів у періоди надмірного зростання поточних витрат.

Ключові слова: симультативна модель, економетричний аналіз, ВВП, споживчі витрати, валове нагромадження капіталу, макроекономічне прогнозування, модель, економічне зростання, макроекономічна динаміка.

Statement of the problem. Macroeconomic modeling plays a critical role in understanding the complex interrelationships between economic variables and forecasting the consequences of economic policy. Traditional single-level regression models often fail to account for the simultaneity and interdependence of macroeconomic indicators, leading to biased estimates and incorrect conclusions. The problem of endogeneity, when explanatory variables correlate with the model's error terms, is particularly relevant in the analysis of macroeconomic data.

The relationship between GDP, consumer spending, and investment is bidirectional: on one hand, GDP is formed as the sum of these components; on the other, the level of income in the economy determines consumption and investment capacity. This simultaneity necessitates the application of specialized econometric methods capable of adequately modeling such linkages.

The relevance of this research stems from the need to develop analytical tools for macroeconomic processes within transitional economies. A precise understanding of the quantitative parameters regarding the mutual influence of major macroeconomic aggregates is a necessary prerequisite for formulating effective fiscal and monetary policies, as well as for making evidence-based economic forecasts.

Analysis of recent research and publications. Theoretical foundations of macroeconomic modeling remain rooted in the Solow model (P. Dykas et al. [1]), post-Keynesian structuralism (E. Stockhammer [2]), and DSGE approaches (Y. Chan [3]; A. Geromichalos & L. Herrenbrueck [4]). Finally, C. Bazán Navarro & R. Benazic Tomé [5] provide stability analysis for the IS-LM-AS framework, completing the theoretical landscape for this study.

Contemporary macroeconomics shifts toward dynamic systems, where T. Warrener et al. [6] and Y. Neog & A. Gaur [7] prove the efficacy of simultaneous equations models for emerging markets. C. Zamfir et al. [8] specifically justify simultaneous equations models for household consumption, while R. Shchur et al. [9] and A. Fedajev et al. [10] expand this via QARDL and PLS-SEM techniques.

Innovative modeling is explored by J. Farmer [11] through agent-based approaches and J. Arias et al. [12] via stochastic volatility. Y. Song et al. [13] and M. Abd El-Aal [14] integrate deep learning and AI into indicator analysis. The evolution of such "super-models" is critically analyzed by O. Helgadóttir [15], while G. Benigno et al. [16] focus on endogenous switching during financial crises.

Highlighting previously unresolved parts of the overall problem. Despite the proliferation of complex DSGE models [3], game theory [17] and AI-driven forecasting [14] in global literature, there remains a distinct lack of transparent, structural econometric frameworks tailored to the specific volatility of transitional economies like Ukraine. Traditional single-equation regression models consistently fail to address the fundamental problem of endogeneity and the bidirectional causality inherent in macroeconomic aggregates. Specifically, the circular relationship where GDP both determines and is determined by consumption and investment creates a "simultaneity bias" that renders standard OLS estimates unreliable for policy formulation. Furthermore, while theoretical literature

emphasizes the identity between savings and investment, empirical verification of the strength of this linkage within a simultaneous system for Ukraine remains insufficient. There is a need to bridge this gap by developing a model that not only accounts for these interdependencies but also identifies which specific drivers retain statistical significance.

Formation of the objectives of the article (task statement). The objective of this research is to develop a simultaneous econometric model describing the interrelationships between GDP, consumption expenditure, and gross capital formation of Ukraine, as well as to estimate its parameters based on macroeconomic data from 2000 to 2021. To achieve this goal, the following tasks were established: constructing the structural form of the simultaneous model with a justification for the selection of endogenous and exogenous variables; verifying the identification of the model through the necessary order and rank conditions; deriving the reduced form of the model and establishing the parametric relationships between the structural and reduced forms; estimating the model parameters using in two-stage least squares methods; and conducting an econometric analysis of the results, including the verification of the statistical significance of the estimated coefficients and the overall adequacy of the model.

Summary of the main research material. The Ukrainian dimension of macroeconomic research based on quantitative methods is addressed by L. Zomchak & D. Miskiv [18] regarding industrial output and L. Zomchak & M. Vdovyn [19] through discriminant analysis of foreign trade. M. Vdovyn [20], O. Dobrovolska [21], and L. Capoani & P. Martini [22] emphasize the impact of full-scale war on GDP dynamics and spatial gravity costs.

In the course of conducting this research, the following variables were selected for analysis: endogenous variables: final consumption expenditure y_1, gross capital formation (y_2), and GDP (y_3); exogenous variables: Average monthly wage (x_1) and gross savings (x_2).

The dataset spans the period from 2000 to 2021, data collected from the official webpage of the State Statistics Service [23]. The structural form of the model is specified as follows:

$$C_t = \alpha_0 + \alpha_1 y_t + \alpha_2 w_t + \epsilon_{1t} \quad (1)$$

$$I_t = \beta_0 + \beta_1 y_t + \beta_2 s_t + \epsilon_{2t} \quad (2)$$

$$y_t = \gamma_0 + \gamma_1 C_t + \gamma_2 I_t + \epsilon_{3t} \quad (3)$$

where C_t – final consumption expenditure; I_t – gross capital formation; y_t – GDP; w_t – average monthly wage; s_t – gross savings.

To facilitate interpretation and the subsequent derivation of the reduced form, the variables have been redefined. The modified structural form is presented as follows:

$$y_1 = \beta_{10} + \beta_{13} y_3 + \gamma_{11} x_1 + \epsilon_1 \quad (4)$$

$$y_2 = \beta_{20} + \beta_{23} y_3 + \gamma_{22} x_2 + \epsilon_2 \quad (5)$$

$$y_3 = \beta_{30} + \beta_{31} y_1 + \beta_{32} y_2 + \epsilon_3 \quad (6)$$

where y_1 – final consumption expenditure; y_2 –gross capital formation; y_3 –GDP; x_1 – average monthly wage; x_2 – gross savings.

In Equation (4), the endogenous variable is final consumption expenditure (y_1), which is determined by GDP (y_3) and the average monthly wage (x_1). GDP serves as a fundamental indicator of national welfare and economic development. Since final consumption expenditure is a component of GDP, fluctuations in the latter necessarily influence consumption levels. Furthermore, the average monthly wage directly impacts consumption, as higher wages enable households to increase spending on goods and services, thereby raising aggregate consumer expenditure.

In Equation (5), gross capital formation (y_3) serves as the endogenous variable, while GDP (y_3) and gross savings (x_2) are treated as exogenous. An increase in GDP enhances a country's international competitiveness and investment attractiveness, leading to higher gross capital formation. According to fundamental economic principles, injections into the economy must equal leakages. Excluding the public and external sectors, investments represent injections, while savings represent leakages; thus, investment is intrinsically supported by savings.

In Equation (6), GDP (y_3) is the endogenous variable, depending on final consumption expenditure (y_1) and gross capital formation (y_2). This specification is consistent with economic theory, as these two indicators are primary components of GDP and directly determine its aggregate value.

The reduced form of the simultaneous model (compact form) is expressed as follows:

$$y_1 = \pi_{10} + \pi_{11} x_1 + \pi_{12} x_2 + \upsilon_1 \quad (7)$$

$$y_2 = \pi_{20} + \pi_{21} x_1 + \pi_{22} x_2 + \upsilon_2 \quad (8)$$

$$y_3 = \pi_{30} + \pi_{31} x_1 + \pi_{32} x_2 + \upsilon_3 \quad (9)$$

According to the order condition of identification analysis, the number of exogenous

variables excluded from an equation ($k - k_i$) must be greater than or equal to the number of endogenous variables included in that equation minus one ($m_i - 1$). The condition is formulated as:

$$k - k_i \geq m_i - 1$$

where m is a total endogenous variables in the model (m = 3); m_i is a endogenous variables in the i-th equation; k is a total exogenous variables in the model (k = 2); k_i is an exogenous variables in the i-th equation.

For this model:

Equation 1: $k-k_1 = m_1-1$; 2-1=2-1, the equation is exactly identified.

Equation 2: $k-k_2 = m_2-1$; 2-1=2-1, the equation is exactly identified.

Equation 3: $k-k_3 = m_3-1$; 2-0=3-1, the equation is exactly identified.

To verify the rank condition, we express the system in a standardized structural form:

$$1y_1 + 0y_2 - \beta_{13}y_3 - \gamma_{11}x_1 + 0x_2 = \beta_{10} + \epsilon_1 \quad (10)$$

$$0y_1 + 1y_2 - \beta_{23}y_3 + 0x_1 - \gamma_{22}x_2 = \beta_{20} + \epsilon_2 \quad (11)$$

$$-\beta_{31}y_1 - \beta_{32}y_2 + 1y_3 + 0x_1 + 0x_2 = \beta_{30} + \epsilon_3 \quad (12)$$

The matrix of structural parameters M_s is:

$$M_s = \begin{pmatrix} 1 & 0 & -\beta_{13} & -\gamma_{11} & 0 \\ 0 & 1 & -\beta_{23} & 0 & -\gamma_{22} \\ -\beta_{31} & -\beta_{32} & 1 & 0 & 0 \end{pmatrix}$$

For each equation, we construct a sub-matrix A_i by deleting the row corresponding to that equation and the columns corresponding to its non-zero coefficients.

$$A_1 = \begin{pmatrix} 1 & -\gamma 22 \\ -\beta 32 & 0 \end{pmatrix} \neq 0 \quad \rightarrow \quad r(A_1)=m-1=2$$

(the equation is exactly identified)

$$A_2 = \begin{pmatrix} 1 & -\gamma 11 \\ -\beta 31 & 0 \end{pmatrix} \neq 0 \quad \rightarrow \quad r(A_2)=m-1=2$$

(the equation is exactly identified)

$$A_3 = \begin{pmatrix} -\gamma 11 & 0 \\ 0 & -\gamma 22 \end{pmatrix} \neq 0 \quad \rightarrow \quad r(A_3)=m-1=2$$

(the equation is exactly identified)

To perform an econometric analysis of the simultaneous model, each constituent equation must be estimated. In the first equation, final consumption expenditure (y_1) serves as the endogenous variable, depending on GDP (y_3) and the average monthly wage (x_1). The estimated equation is expressed as y_1 = 25781,94 + 0,55 y_3 + 134,52 x_1.

Since the parameters γ_{11} and β_{13} are non-zero, the sample data indicate a correlation between GDP, the average monthly wage, and final consumption expenditure. The positive values of these parameters suggest that as GDP and wages increase, the average level of consumption expenditure rises. Specifically, $\beta_{13} = 0,55$ implies that a 1 million UAH increase in GDP results in an average increase in consumption of 0,55 million UAH. Similarly, $\gamma_{11} = 134,52$ indicates that a 1 UAH increase in the average monthly wage leads to an increase in consumption expenditure of 134,52 UAH. The coefficient of multiple determination (R^2) is 0.996, signifying that 99.6% of the variation in final consumption expenditure is explained by the model.

To test the statistical significance of β_{13}, the null hypothesis $H_0 : \beta_{13} = 0$ is formulated. The empirical t-statistic is $t_{emp} = 2,46$. At a significance level of $\alpha = 0.05$ and 19 degrees of freedom, the critical value is $t_{cryt} = 1,73$. Because $t_{emp} > t_{cryt}$, the null hypothesis is rejected with a 95% confidence level, confirming that the relationship between GDP and consumption is statistically significant. For γ_{11}, the null hypothesis $H_0 : \gamma_{11} = 0$ is tested with an empirical value of $t_{emp} = 1.63$. Since $t_{emp} < t_{cryt}$, the null hypothesis is accepted, indicating that the impact of the average monthly wage on consumption is statistically insignificant. The overall model adequacy is confirmed by the F-test, as $F_{emp} = 2405,07$ significantly exceeds $F_{cryt} = 3,5$.

In the second equation, gross capital formation (y_2) is the endogenous variable, while GDP (y_3) and gross savings (x_2) are exogenous. The estimated equation is y_2 = -218,26 – 0,034 y_3 + 1,3 $\tilde{o}_2$. The positive γ_{22} indicates that higher savings correspond to increased capital formation, while the negative β_{23} suggests that capital formation decreases as GDP rises. Specifically, $\gamma_{22} = 1,3$ implies that a 1 million UAH increase in savings leads to a 1,3 million UAH increase in capital formation. The R^2 of 0.94 shows that 93.7% of the variation is explained by the independent variables. Testing $\beta_{23} yields\, t_{emp} = 1,06$, which is less than $t_{cryt} = 1,73$, rendering the impact of GDP statistically insignificant with 0,95, but it is significant with 0,87. However, the t-test for γ_{22} ($t_{emp} = 5,37$) confirms a statistically significant relationship. The model as a whole is adequate, as $F_{emp} = 141,12 > F_{cryt} = 3,5$.

The third equation defines GDP (y_3) as a function of final consumption expenditure (y_1) and gross capital formation (y_2), resulting in $y_3 = 27607,76 + 1,03y_1 + 0,49y_2$. While this equation is strictly grounded in economic theory, such a specification results in a statistically insignificant coefficient for the gross capital

formation variable. From an econometric perspective, the model cannot be maintained in this form. This issue was successfully resolved by replacing gross capital formation with gross savings. The modified equation takes the following form: $y_3 = 27051,42 + 1,01y_1 + 0,63x_2$. The positive parameters β_{32}, β_{31} indicate that GDP increases alongside consumption and savings. Specifically, $\beta_{31} = 1,01$ shows that a 1 million UAH rise in consumption increases GDP by 1,01 million UAH. The R^2 of 0,996 reflects a high degree of explanatory power. The t-test for β_{31} produced a highly significant result ($t_{emp} = 21.04$), while the test for β_{32} show that it is significant with 0,87. Nevertheless, the F-statistic of 2164.82 confirms the overall adequacy and validity of the model at the 95% confidence level.

Therefore, the final system of equations, including the calculated coefficients, takes the following form:

$$y_1 = 25781,94 + 0,55\, y_3 + 134,52\, x_1,$$
$$y_2 = -218,26 - 0,034\, y_3 + 1,3\, x_2,$$
$$y_3 = 27051,42 + 1,01y_1 + 0,63x_2.$$

All parameters within the model demonstrate statistical significance, with the R-squared values for each equation surpassing 0.94.

Conclusions. The research resulted in the development and validation of a simultaneous equations model designed to analyze the interdependencies among key macroeconomic indicators, namely GDP, final consumption expenditure, and gross capital formation. The identification analysis confirmed that all equations in the system are exactly identified, which justified the use of the two-stage least squares method for parameter estimation. The estimation results demonstrate high explanatory power, with the coefficients of determination for the consumption, investment, and GDP equations reaching 0,996; 0,937 and 0,996, respectively. These figures confirm the specification adequacy of the model and the appropriateness of the selected explanatory variables.

Statistical testing revealed varying levels of significance across specific relationships; however, the most robust links were identified between GDP and consumption expenditure and between gross savings and capital formation. The F-test results confirmed the overall adequacy of all three equations, establishing their reliability for analytical and forecasting purposes. The marginal propensity to consume, estimated at 0,55, aligns with established economic theory and empirical evidence from prior research. Furthermore, a coefficient of 1,3 for gross savings within the investment function suggests a multiplier effect of savings on capital accumulation.

Future research perspectives involve expanding the model's scope by incorporating additional endogenous variables, such as employment, inflation, and net exports. Further focus should be placed on accounting for structural shifts within the study period through the application of time-varying parameter models and the assessment of their temporal stability. Additionally, there is significant potential in conducting a comparative analysis of different simultaneous equation estimators and applying the developed framework to construct macroeconomic forecasts based on a scenario-based approach.

REFERENCES:

1. Dykas, P., Tokarski, T., & Wisła, R. (2023). *The Solow model of economic growth: Application to contemporary macroeconomic issues*. Taylor & Francis. https://doi.org/10.4324/9781003323792

2. Stockhammer, E. (2023). Macroeconomic ingredients for a growth model analysis for peripheral economies: A post-Keynesian-structuralist approach. *New Political Economy*, *28*(4), 628–645. https://doi.org/10.1080/13563467.2022.2149723

3. Chan, Y. T. (2022). The macroeconomic impacts of the COVID-19 pandemic: A SIR-DSGE model approach. *China Economic Review*, *71*, Article 101725. https://doi.org/10.1016/j.chieco.2021.101725

4. Geromichalos, A., & Herrenbrueck, L. (2022). The liquidity-augmented model of macroeconomic aggregates: A New Monetarist DSGE approach. *Review of Economic Dynamics*, *45*, 134–167. https://doi.org/10.1016/j.red.2021.05.002

5. Bazán Navarro, C. E., & Benazic Tomé, R. M. (2022). Structural stability analysis in a dynamic IS-LM-AS macroeconomic model with inflation expectations. *International Journal of Differential Equations*, *2022*(1), Article 5026061. https://doi.org/10.1155/2022/5026061

6. Warrener, T. C., Silva, R. F., & Di Guimarães, L. (2023). Financial system and economic development: A study for emerging countries through a system of simultaneous equations. *Revista Eletrônica de Negócios Internacionais: Internext*, *18*(3), 235–249. https://doi.org/10.18568/internext.v18i3.741

7. Neog, Y., & Gaur, A. K. (2020). Macro-economic determinants of tax revenue in India: An application of dynamic simultaneous equation model. *International Journal of Economic Policy in Emerging Economies*, *13*(1), 13–35. https://doi.org/10.1504/ijepee.2020.106679

8. Zamfir, C. G., Lupaşc, A., & Lupaşc, I. (2012). Simultaneous equations model used in studying the analysis on household final consumption. *Revista Economică*, *189*.

9. Shchur, R., Pilko, A., Chepyha, B., Bilyi, M., & Stabias, S. (2025). Application of SEM and QARDL models in the practice of analysis of the influence of exchange rate volatility on macroeconomic indicators. *Financial and Credit Activity: Problems of Theory and Practice*, *1*(60), 20–32. https://doi.org/10.55643/fcaptp.1.60.2025.4669

10. Fedajev, A., Pantović, D., Milošević, I., Vesić, T., Jovanović, A., Radulescu, M., & Stefan, M. C. (2023). Evaluating the outcomes of monetary and fiscal policies in the EU in times of crisis: A PLS-SEM approach. *Sustainability*, *15*(11), Article 8466. https://doi.org/10.3390/su15118466

11. Farmer, J. D. (2025). Quantitative agent-based models: A promising alternative for macroeconomics. *Oxford Review of Economic Policy*, *41*(2), 571–590. https://doi.org/10.1093/oxrep/graf027

12. Arias, J. E., Rubio-Ramirez, J. F., & Shin, M. (2023). Macroeconomic forecasting and variable ordering in multivariate stochastic volatility models. *Journal of Econometrics*, *235*(2), 1054–1086. https://doi.org/10.1016/j.jeconom.2022.04.013

13. Song, Y., Tang, X., Wang, H., & Ma, Z. (2023). Volatility forecasting for stock market incorporating macroeconomic variables based on GARCH-MIDAS and deep learning models. *Journal of Forecasting*, *42*(1), 51–59. https://doi.org/10.1002/for.2899

14. Abd El-Aal, M. F. (2025). The relationship between CO2 emissions and macroeconomics indicators in low and high-income countries: Using artificial intelligence. *Environment, Development and Sustainability*, *27*(12), 29493–29514. https://doi.org/10.1007/s10668-024-04880-3

15. Helgadóttir, O. (2023). How to make a super-model: Professional incentives and the birth of contemporary macroeconomics. *Review of International Political Economy*, *30*(1), 252–280. https://doi.org/10.1080/09692290.2021.1997786

16. Benigno, G., Foerster, A., Otrok, C., & Rebucci, A. (2025). Estimating macroeconomic models of financial crises: An endogenous regime-switching approach. *Quantitative Economics*, *16*(1), 1–47. https://doi.org/10.3982/qe2038

17. Vdovyn, M., Zomchak, L., & Panchyshyn, T. (2022). Modeling of economic systems using game theory. *Věda a Perspektivy*, *7*(7), 14. https://doi.org/10.52058/2695-1592-2022-7(14)-91-100

18. Zomchak, L., & Miskiv, D. (2024). Structural model of Ukrainian economic performance: Interactions between GDP and industrial output. *Smart Economy, Entrepreneurship and Security*, *2*(2), 7–16. https://doi.org/10.60022/sis.2.2-1

19. Zomchak, L., & Vdovyn, M. (2026). Discriminant analysis of foreign economic activity of Central and Eastern European countries. *Problems of Systemic Approach in Economy*, *1*(103), 34–41. https://doi.org/10.32782/2520-2200/2026-1-4

20. Vdovyn, M. (2025). Ukraine's position in the fragile states index: Conflict, threats and challenges. In *Accreditation of educational programs: Foreign experience: Materials of the All-Ukrainian scientific and pedagogical professional development (June 23 – August 3, 2025)* (pp. 17–20). Liha-Pres.

21. Dobrovolska, O., Kolotilina, O., & Ostapenko, M. (2024). Forecasting macroeconomic dynamics in Ukraine: The impact of a full-scale war. *SocioEconomic Challenges*, *8*(3), 211–237. https://doi.org/10.61093/sec.8(3).211-237.2024

22. Capoani, L., & Martini, P. (2026). The cost of proximity: A spatial gravity model of the Ukraine war's economic impact. *Networks and Spatial Economics*, *26*(1), 331–359. https://doi.org/10.1007/s11067-025-09699-7

23. State Statistics Service of Ukraine. (n.d.). Official website. https://stat.gov.ua/en (access date: 03.03.2026).

СПИСОК ВИКОРИСТАНИХ ДЖЕРЕЛ:

1. Dykas P., Tokarski T., Wisła R. The Solow model of economic growth: Application to contemporary macroeconomic issues. Taylor & Francis, 2023. 265 p.

2. Stockhammer E. Macroeconomic ingredients for a growth model analysis for peripheral economies: a post-Keynesian-structuralist approach. *New Political Economy*. 2023. Vol. 28, No. 4. P. 628–645.

3. Chan Y. T. The macroeconomic impacts of the COVID-19 pandemic: A SIR-DSGE model approach. *China Economic Review*. 2022. Vol. 71. Art. 101725.

4. Geromichalos A., Herrenbrueck L. The liquidity-augmented model of macroeconomic aggregates: A New Monetarist DSGE approach. *Review of Economic Dynamics*. 2022. Vol. 45. P. 134–167.

5. Bazán Navarro C. E., Benazic Tomé R. M. Structural Stability Analysis in a Dynamic IS-LM-AS Macroeconomic Model with Inflation Expectations. *International Journal of Differential Equations*. 2022. Vol. 2022(1). Art. 5026061.

6. Warrener T. C., Silva R. F., Di Guimarães L. Financial system and economic development: a study for emerging countries through a system of simultaneous equations. *Revista Eletrônica de Negócios Internacionais: Internext*. 2023. Vol. 18, No. 3. P. 235–249.

7. Neog Y., Gaur A. K. Macro-economic determinants of tax revenue in India: an application of dynamic simultaneous equation model. *International Journal of Economic Policy in Emerging Economies*. 2020. Vol. 13, No. 1. P. 13–35.

8. Zamfir C. G., Lupaşc A., Lupaşc I. Simultaneous Equations Model Used In Studying The Analysis On Household Final Consumption. *Revista Economică*. 2012. Vol. 189.

9. Application of SEM and QARDL models in the practice of analysis of the influence of exchange rate volatility on macroeconomic indicators / R. Shchur et al. *Financial and credit activity problems of theory and practice*. 2025. Vol. 1(60). P. 20–32.

10. Evaluating the outcomes of monetary and fiscal policies in the EU in times of crisis: A PLS-SEM approach / A. Fedajev et al. *Sustainability*. 2023. Vol. 15, No. 11. Art. 8466.

11. Farmer J. D. Quantitative agent-based models: a promising alternative for macroeconomics. *Oxford Review of Economic Policy*. 2025. Vol. 41, No. 2. P. 571–590.

12. Arias J. E., Rubio-Ramirez J. F., Shin M. Macroeconomic forecasting and variable ordering in multivariate stochastic volatility models. *Journal of Econometrics*. 2023. Vol. 235, No. 2. P. 1054–1086.

13. Volatility forecasting for stock market incorporating macroeconomic variables based on GARCH-MIDAS and deep learning models / Y. Song et al. *Journal of Forecasting*. 2023. Vol. 42, No. 1. P. 51–59.

14. Abd El-Aal M. F. The relationship between CO2 emissions and macroeconomics indicators in low and high-income countries: using artificial intelligence. *Environment, Development and Sustainability*. 2025. Vol. 27, No. 12. P. 29493–29514.

15. Helgadóttir O. How to make a super-model: professional incentives and the birth of contemporary macroeconomics. *Review of international political economy*. 2023. Vol. 30, No. 1. P. 252–280.

16. Vdovyn M., Zomchak L., Panchyshyn T. Modeling of Economic systems using game theory. *Věda a perspektivy*. 2022. Vol. 7, No. 7. P. 14.

17. Estimating macroeconomic models of financial crises: An endogenous regime-switching approach / G. Benigno et al. *Quantitative Economics*. 2025. Vol. 16, No. 1. P. 1–47.

18. Zomchak L., Miskiv D. Structural model of Ukrainian economic performance: interactions between GDP and industrial output. *Smart Economy, Entrepreneurship and Security*. 2024. Vol. 2, No. 2. P. 7–16.

19. Zomchak L., Vdovyn M. Discriminant analysis of foreign economic activity of Central and Eastern European countries. *Problems of Systemic Approach in Economy*. 2026. Vol. 1(103). P. 34–41.

20. Vdovyn M. Ukraine's position in the fragile states index: Conflict, threats and challenges. *Accreditation of educational programs: Foreign experience: Materials of the All-Ukrainian scientific and pedagogical professional development (June 23 – August 3, 2025)*. Liha-Pres, 2025. P. 17–20.

21. Dobrovolska O., Kolotilina O., Ostapenko M. Forecasting macroeconomic dynamics in Ukraine: The impact of a full-scale war. *SocioEconomic Challenges*. 2024. Vol. 8, No. 3. P. 211–237.

22. Capoani L., Martini P. The Cost of Proximity: A Spatial Gravity Model of the Ukraine War's Economic Impact. *Networks and Spatial Economics*. 2026. Vol. 26, No. 1. P. 331–359.

23. State Statistics Cervice of Ukraine : official web-page. URL: https://stat.gov.ua/en (access date: 03.03.2026).

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