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STRUCTURAL MODEL OF UKRAINIAN ECONOMIC PERFORMANCE: INTERACTIONS BETWEEN GDP AND INDUSTRIAL OUTPUT

Abstract. *This paper presents an empirical analysis of the economic development of Ukraine from 2001 to 2021, utilizing a structural simultaneous model to examine the interactions between key economic variables. The study focuses on three resulting variables: Gross Domestic Product (GDP), the volume of industrial products sold, and the volume of industrial products produced. These are modeled as dependent on four factor variables: exports of goods, imports of goods, average monthly salary, and capital investments in industry. The model aims to quantify how these factors influence Ukraine's economic performance, with particular attention to industrial output and trade dynamics. Through a series of structural equations, the paper explores the relationships between these variables, revealing that industrial production, wages, and exports play significant roles in driving GDP growth. Additionally, imports contribute to industrial production and sales, suggesting that they serve as vital inputs for domestic manufacturing. The results indicate that while exports have a negative impact on GDP, likely due to the dominance of raw material exports, higher wages and capital investments have a positive effect on economic growth. The model is statistically significant at a 95% confidence level, and its findings provide valuable insights for policymakers seeking to enhance industrial growth and optimize trade and investment strategies for sustainable economic development in Ukraine.*

Keywords: *economic development, structural modelling, macroeconomic modelling, economic growth, GDP, industrial output, economic policy, economic performance, industrial products, export, import, capital investment, model.*

1. Introduction

The economic development of a country is influenced by a multitude of factors, which often interact in complex ways. Understanding these dynamics is crucial for formulating effective policies that promote sustainable growth and industrial development. In this paper, we examine the economic development of Ukraine over the period from 2001 to 2021, focusing on the relationships between key economic indicators, such as Gross Domestic Product (GDP), industrial output, exports, imports, wages, and capital investments. Ukraine's economy, like that of many developing countries, faces significant challenges, including fluctuations in industrial output, reliance on exports of raw materials, and the need for substantial capital investment in industry. At the same time, its economy has been impacted by both internal and external shocks and war, making it important to explore how various economic factors contribute to its growth.

To analyze these relationships, we construct a structural simultaneous model that captures the interactions between three output variables — GDP, the volume of industrial products sold, and the volume of industrial products produced — and four key factor variables: exports, imports, average monthly wage, and capital investments in industry. This model is designed to provide insights into the relative influence of these factors on Ukraine's economic performance, to discover interdependencies between these indicators and to offer a better understanding of the mechanisms behind economic growth. By identifying the linkages between these variables, we aim to shed light on the role of trade, industrial productivity, and wages in shaping the country's economic trajectory.

The theoretical foundation of this study draws from classical and contemporary economic theories on growth and development, emphasizing the importance of industrial output and trade in driving economic expansion. The paper also builds on previous empirical work, which has explored the relationship between GDP and industrial production, as well as the role of exports, imports, and capital investment in fostering economic development. The unique contribution of this study lies in its empirical approach, using a multi-equation structural model to quantify the interactions between these key factors and provide policy-relevant insights for the Ukrainian economy.

In the following sections, we present the model, the data used for estimation, and the results of the empirical analysis. We also discuss the implications of our findings for understanding the dynamics of Ukraine's economic development and suggest potential policy measures to improve industrial growth and economic stability.

The relationship between Gross Domestic Product (GDP) and industrial output has been widely studied, as it reflects the critical role industrialization plays in economic growth. Industrial output is often considered a crucial driver of economic growth. Aslam et al. [1] explore this dynamic in the context of China, revealing how industrialization not only contributes to GDP per capita growth but also impacts CO_2 emissions. Similarly, Ughulu [2] finds that in emerging economies, including Nigeria, industrial output plays a significant role in boosting GDP, especially through the export of industrial goods, which spurs economic development.

Electricity consumption is another critical factor that connects industrial output with GDP. Abbasi et al. [3] provide empirical evidence from Pakistan, showing that electricity consumption in the industrial sector directly influences GDP growth. Lehmann and Möhrle [4] extend this idea by utilizing high-frequency electricity consumption data to forecast regional industrial production. Climate-related factors, such as temperature, also affect industrial output, as shown by Colmer [5]. Technological advancements are also central to the relationship between GDP and industrial output. Hidayatno et al. [6] further explore this by focusing on Industry 4.0 technologies, which are transforming industrial output and energy consumption patterns. Artar [7] addresses the role of the real effective exchange rate in influencing industrial output in Turkey.

Wang and Zhao [8] analyze regional differences in industrial carbon emissions in China, uncovering variations in industrial productivity and its environmental impact across regions. These regional differences can result in divergent GDP growth patterns, with more industrialized regions experiencing faster economic growth due to higher industrial output. The effect of industrial structure on economic recovery has been explored by Zhang and Dilanchiev [9]. Parveen et al. [10] examine the influence of industrial output, financial development, and energy (both renewable and non-renewable) on environmental degradation in newly industrialized countries.

The relationship between GDP and industrial output in Ukraine is shaped by factors such as resilience to economic shocks, technological competitiveness, and the role of economic policies. Studies like those by Lebedeva et al. [11] highlight the vulnerability of Ukraine's industry to external disruptions, while Koval et al. [12] emphasize the importance of effective industrial policies and investment to drive GDP growth. Post-war recovery strategies, explored by Kushnirenko et al. [13], suggest that sustainable development and technological advancements are key for rebuilding industrial capacity. Additionally, Ukraine's technological lag, noted by Matyushenko et al.[14], limits industrial output, but closer EU integration could enhance competitiveness.

The literature on methods and models for analyzing the relationship between industrial output and economic growth employs a wide range of approaches, each providing valuable insights into economic dynamics. Xie et al. [15] use the LMDI (Logarithmic Mean Divisia Index) method to analyze the decoupling relationship between CO_2 emissions and GDP in China's power industry, offering insights into how industrial output can grow while reducing environmental impact. Jiang [16] applies machine learning techniques to predict local GDP and analyze industrial structure, demonstrating the utility of data-driven models in forecasting economic performance. Demir [17] uses the ARDL (Autoregressive Distributed Lag) bounds test to analyze the effect of employment in the agricultural and industrial sectors on economic growth, showing the interdependence of different sectors. Fornaro [18] explores nowcasting industrial production using unconventional data sources, while Bozkus et al. [19] apply multifractal analysis to examine the relationship between atmospheric carbon emissions and industrial production in OECD countries. Dragomir et al. [20] use Bayesian analysis to study the impact of CO_2 emissions and industrial production on Romania's economy, offering a probabilistic approach to understanding economic and environmental interactions. Zomchak and Stelmakh [21] uses an ARIMA model to forecast macroeconomic indicators in Ukraine, providing insights into the predictive power of time series models. Zomchak et al. [22] used simultaneous equations for modeling interdependences between GDP and capital investments. In a similar vein, Chandio et al. [23] use cointegration and causality analysis to examine the dynamic link between industrial energy consumption and economic growth in Pakistan, while Lee and Park [24] focus on nowcasting industrial production in Korea. Ilyash et al. [25] conduct a multidimensional analysis to forecast the relationship between industrial-technological development and economic security in Ukraine. Finally, Sampi Bravo et al. [26] use Google Community Mobility Reports to nowcast economic activity during the COVID-19 pandemic, demonstrating how real-time data can be used for forecasting in times of crisis. Zhang and Ma [27] employ a dynamic threshold panel model to investigate the relationship between industrial structure and carbon intensity across different stages of economic development in China, highlighting the model's ability to capture non-linear effects and varying thresholds in industrial and environmental dynamics. Chamalwa et al. [28] use an Autoregressive Distributed Lag (ARDL) model to analyze the relationship between Nigeria's GDP, exchange rate, and foreign import trade, demonstrating the model's suitability for examining short- and long-term dynamics in economic variables. Vdovyn et al. [29] used statistical methods for estimation of foreign trade between EU and Ukraine impact. Another paper by Vdovyn et al. [30] is dedicated to regional development of Ukraine and based on taxonomic analysis. Verbivska et al. [31] focus on forecasting macroeconomic indicators for Ukraine's economy during the war period (2022–2023), utilizing advanced forecasting methods to predict economic trends under highly uncertain conditions. Together, these studies showcase a range of advanced methodologies, from machine learning and Bayesian analysis to ARIMA and nowcasting, that are increasingly used to model the complex interactions between industrial output, economic growth, and environmental sustainability.

The studies reviewed underscore the multifaceted relationship between GDP and industrial output. While industrialization remains a key driver of economic growth, this process is influenced by various factors, including energy consumption, climate conditions, technological innovation, and regional disparities. The literature suggests that for industrial output to positively contribute to GDP growth in a sustainable manner, policymakers must consider environmental impacts, energy efficiency, and technological advancements. Furthermore, regional and climate-specific factors must be taken into account, as these can alter the efficiency and sustainability of industrial production, which ultimately affects the broader economic landscape. Future research should explore how these factors interact in different contexts, especially in developing economies, to create a comprehensive understanding of the dynamics between industrial output and GDP growth.

2. Materials and Methods

A system of simultaneous equations (SSE) is a statistical model consisting of a set of linear equations that are solved simultaneously. Unlike ordinary regression models, SSE involves two or more dependent variables. The variables that are explained by the interactions within the system and whose values are determined through the simultaneous relationships in the model are termed endogenous variables or jointly determined variables. On the other hand, exogenous variables, or predetermined variables, are those that influence the endogenous variables but whose values are determined outside the system. Exogenous variables play a critical role in explaining the variations observed in endogenous variables.

The classification of variables as endogenous or exogenous is typically determined by the model developer, often relying on expert judgment in the process. The dependent variables in this research include GDP (y_1), the volume of industrial products sold (y_2), and the volume of industrial products produced by business entities of various economic activities (y_3). The independent variables include exports (x_1), imports (x_2), average monthly salary (x_3), and capital investments in industry (x_4).

We hypothesize that industrial production, trade, wages, and capital investments exert significant influence on Ukraine's GDP and industrial output.

Table 1

Indicators for simultaneous model of production connection with GDP in Ukraine

Indicator	Sense of the indicator	Units of measurement
y_1	GDP	million UAH
y_2	volume of industrial products sold	million UAH
y_3	volume of industrial products produced by business entities of various economic activities	thousand UAH
x_1	Export of goods	million UAH
x_2	Import of goods	million UAH
x_3	average monthly salary	UAH
x_4	capital investments in industry	million UAH

Source: Combination of indicators proposed by the authors

Specifically, the model posits that GDP is a function of industrial output and key economic factors such as exports, wages, and capital investments. Similarly, the volume of industrial products sold is assumed to depend on the volume of industrial production, imports, and capital investments. Finally, the volume of industrial output is hypothesized to be influenced by GDP and imports.

The model is tested using statistical data for the period 2001–2021 collected from the official webpage of the State Statistic Service of Ukraine [33]. The order condition for model identification is applied to ensure that the system of equations is identified and can be estimated. The relationships between the variables are estimated using regression analysis, and the results are evaluated for statistical significance and economic interpretability. More about input data in the Table 1

When discussing economic feasibility, Gross Domestic Product (GDP) serves as a key indicator of a country's economic activity. It represents the total value of all goods and services produced within a country over a specific period. Four key variables — exports of goods, imports of goods, average monthly wages, and capital investment — can significantly influence a country's GDP.

Exports of goods play a crucial role in shaping GDP. When a country exports goods, it sells products to other nations, and the income generated from these exports contributes directly to the national GDP. The higher the value of exports, the greater the potential for GDP growth. Conversely, imports of goods also impact GDP. When a country imports goods, it purchases products from foreign markets, and the expenditure on these imports can detract from GDP. If imports exceed exports, it can result in a trade deficit, which may negatively affect the country's economy.

The average monthly salary is another important factor influencing GDP. Higher wages generally lead to increased consumer spending, which in turn boosts demand for goods and services. This heightened demand can spur production, ultimately driving GDP growth.

Capital investment in industry is also a critical determinant of GDP. When businesses invest in capital goods such as machinery and equipment, productivity tends to increase. Higher productivity can lead to an expansion in industrial output, which positively contributes to GDP growth.

The volume of industrial products produced and sold is closely tied to these variables. Exports, for example, not only generate revenue but can also increase demand for goods and services. As demand rises, industrial production must scale up to meet this need, fostering economic growth. Additionally, exports can create jobs and stimulate economic activity, further boosting industrial production. On the other hand, imports can affect domestic industrial sales by increasing competition in the local market. If imported goods outcompete domestic products, demand for locally produced goods may decrease, leading to a reduction in industrial sales. However, imports can also provide access to goods and raw materials unavailable domestically, which could enhance industrial production.

Average monthly wages influence industrial output as well. When wages are higher, workers have greater purchasing power, which increases demand for goods and services, driving industrial production. Furthermore, higher wages can improve job satisfaction and reduce employee turnover, both of which contribute to enhanced productivity and industrial output.

Finally, capital investment plays a significant role in industrial production. By investing in new equipment, technology, and infrastructure, businesses can boost their productivity and efficiency. This, in turn, can lead to increased production and sales of industrial goods. Moreover, capital investment often results in job creation, which stimulates both economic growth and industrial output.

The structure of the relationships between dependent and independent variables is described using a structural simultaneous model. In its general form, it can be expressed as follows:

$$
\begin{aligned}
y_{1t} &= \beta_{12}y_{2t} + \beta_{13}y_{3t} + \ldots + \beta_{1m}y_{mt} + \gamma_{11}x_{1t} + \gamma_{12}x_{2t} + \\
&\quad + \ldots + \gamma_{1k}x_{kt} + u_{1t}, \\
y_{2t} &= \beta_{21}y_{1t} + \beta_{23}y_{3t} + \ldots + \beta_{2m}y_{mt} + \gamma_{21}x_{1t} + \gamma_{22}x_{2t} + \\
&\quad + \ldots + \gamma_{2k}x_{kt} + u_{2t}, \\
y_{3t} &= \beta_{31}y_{1t} + \beta_{32}y_{2t} + \ldots + \beta_{3m}y_{mt} + \gamma_{31}x_{1t} + \gamma_{32}x_{2t} + \\
&\quad + \ldots + \gamma_{3}x_{kt} + u_{3t}, \\
&\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\
y_{mt} &= \beta_{m1}y_{1t} + \beta_{m2}y_{2t} + \ldots + \beta_{mm-1}y_{m-1t} + \gamma_{m1}x_{1t} + \\
&\quad + \gamma_{m2}x_{2t} + \ldots + \gamma_{mk}x_{kt} + u_{mt},
\end{aligned}
$$

where β and γ — structure model parametres, y_m — dependent variables, x_k — independent variables, $t = 1, \ldots N$ — number of observations and u_m — random variables.

The structural form of the model of the simultaneous model of Ukrainian GDP and industrial output interconnection will look like this:

$$
\begin{aligned}
y_1 &= a_{10} + b_{12}y_2 + a_{11}x_1 + a_{12}x_3 + e_1, \\
y_2 &= a_{20} + b_{23}y_3 + a_{21}x_2 + a_{22}x_4 + e_2, \\
y_3 &= a_{30} + b_{31}y_1 + a_{32}x_2 + e_3.
\end{aligned}
$$

where a_{ij} — intercepts, b_{ij} — parameters of the model, e — random values, y_1 GDP, y_2 the volume of industrial products sold, y_3 the volume of industrial products produced by business entities of various economic activities, x_1 exports, x_2 imports, x_3 average monthly salary, x_4 capital investments in industry.

This system of equations models the relationships between three output variables (GDP, volume of industrial output, volume of industrial output) and four factor variables (exports, imports, average monthly salary, capital investment). All of these variables interact with each other, and changes in one variable can affect the others.

The first equation describes how GDP (y_1) depends on the volume of industrial production (y_2), exports (x_1), average monthly salary (x_3), and some random error.

The second equation describes how the volume of industrial output sold (y_2) depends on the volume of industrial output produced (y_3), imports (x_2) and capital investment (x_4), as well as random errors.

The third equation describes how the volume of industrial output (y_3) depends on GDP (y_1) and imports of goods (x_2), as well as random factors.

After that, we need to check the model for identification using the order condition according to the formula

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

where m_i — number of resulting variables in each i-th equation of the simultaneous model;

k — the total number of factor variables in the simultaneous model;

k_i — the number of factor variables in a separate i-th equation of the model.

If, $k - k_i = m_i - 1$, then the equation is identified.

If, $k - k_i > m_i - 1$, then the equation is overidentified.

Let's check our first equation: 4–2 $\geq$ 2–1 — the equation is a overidentification;

Let's check our second equation: 4–2 $\geq$ 2–1 — the equation is a overidentification;

Let's check our third equation: 4–1 $\geq$ 2–1 — the equation is a overidentification.

To estimate the parameters of the overidentified equations and the model as a whole, the least squares method is not applicable. This is because it would not yield unambiguous structural parameters from the reduced form parameter values of the simultaneous model, as these may correspond to multiple possible solutions. To address this issue, alternative estimation techniques are employed to resolve such ambiguity. The following methods are commonly used in this context: two-stage least squares (2SLS) method, three-stage least squares (3SLS) method, full information maximum likelihood method, instrumental variables method, limited information maximum likelihood method, mixed estimation method and other. We will use the first one.

Also, we can write the abbreviated formula in a collapsed form for the simultaneous model:

$$\begin{cases} y_{1t} = \pi_{10} + \pi_{11}x_{1t} + \pi_{12}x_{2t} + \ldots + \pi_{1k-1}x_{k-1t} + \pi_{1k}x_{kt} + v_{1t}, \\ y_{2t} = \pi_{20} + \pi_{21}x_{1t} + \pi_{22}x_{2t} + \ldots + \pi_{2k-1}x_{k-1t} + \pi_{2k}x_{kt} + v_{2t}, \\ y_{3t} = \pi_{30} + \pi_{31}x_{1t} + \pi_{32}x_{2t} + \ldots + \pi_{3k-1}x_{k-1t} + \pi_{3k}x_{kt} + v_{3t}, \\ y_{4t} = \pi_{40} + \pi_{41}x_{1t} + \pi_{42}x_{2t} + \ldots + \pi_{4k-1}x_{k-1t} + \pi_{4k}x_{kt} + v_{4t}, \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ y_{it} = \pi_{i0} + \pi_{i1}x_{1t} + \pi_{i2}x_{2t} + \ldots + \pi_{ik-1}x_{k-1t} + \pi_{ik}x_{kt} + v_{it} \end{cases}$$

where the coefficients π are the unknown parameters of the model in a reduced form, which are expressed in terms of structural parameters, and v are random variables, which are also expressed in terms of structural parameters of the simultaneous model.

And for the proposed model of the GDP and industrial output of Ukraine it will look like this:

$$y_1 = \pi_{10} + \pi_{11}x_1 + \pi_{12}x_2 + \pi_{13}x_3 + \pi_{14}x_4 + v_1,$$

$$y_2 = \pi_{20} + \pi_{21}x_1 + \pi_{22}x_2 + \pi_{23}x_3 + \pi_{24}x_4 + v_2,$$

$$y_3 = \pi_{30} + \pi_{31}x_1 + \pi_{32}x_2 + \pi_{33}x_3 + \pi_{34}x_4 + v_3,$$

where the coefficients π are the unknown parameters of the model in a reduced form, which are expressed in terms of structural parameters, and v are random variables, which are also expressed in terms of structural parameters of the simultaneous model.

3. Results and Discussion

Therefore, the next step is to calculate the theoretical y, which will also act as factor variables in our model. After that, we can use these values as factor variables in the structural form equations.

The first equation results are in the Table 2, the second equation results are in the Table 3, the third equation results are in the Table 4.

So the final result will give us the following equations:

$$y_1 = -7932.62 + 2.28y_2 - 7.17x_1 + 3.59x_3,$$

$$y_2 = 21510.22 - 7.22y_3 + 78.9x_2 + 0.0001x_4,$$

$$y_3 = -1163789691 - 1154481.29y_1 + 5033.6x_2,$$

where y_1 GDP, y_2 the volume of industrial products sold, y_3 the volume of industrial products produced by business entities of various economic activities, x_1 exports, x_2 imports, x_3 average monthly salary, x_4 capital investments in industry.

As we can see from table 2, the coefficients of the equation are statistically significant, providing valuable insights into the interconnections between

Table 2

Econometric analysis of the first equation

	Coefficients	**Standard Error**	**t Stat**	**P-value**	**Lower 95%**	**Upper 95%**	**Lower 95,0%**	**Upper 95,0%**
Intercept	-7932,63	29489,07	-0,27	0,79	-70149,11	54283,86	-70149,11	54283,86
y_2	3,59	0,30	11,98	0,00	2,96	4,23	2,96	4,23
x_1	-7,17	0,91	-7,87	0,00	-9,09	-5,25	-9,09	-5,25
x_3	2,28	0,33	6,91	0,00	1,59	2,98	1,59	2,98

Source: Calculated by the authors

Table 2

Econometric analysis of the second equation

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95,0%	Upper 95,0%
Intercept	21510,23	57516,53	0,37	0,71	-99839,05	142859,50	-99839,05	142859,50
y_3	0,00	0,00	7,25	0,00	0,00	0,00	0,00	0,00
x_2	78,90	32,46	2,43	0,03	10,42	147,38	10,42	147,38
x_3	-7,22	1,71	-4,21	0,00	-10,83	-3,60	-10,83	-3,60

Source: Calculated by the authors

industrial output, exports, and average monthly salary in the context of GDP. However, the non-significance of the intercept suggests that additional model refinement may be needed to capture the full dynamics of the economic relationships.

The regression analysis of the first equation, which models the relationship between GDP and the volume of industrial products sold, and average monthly salary, shows a very strong correlation with a Multiple R value of 0.999. The R-squared value of 0.9985 indicates that approximately 99.85% of the variation in GDP can be explained by the independent variables in the model. The adjusted R-squared of 0.9983 further confirms the robustness of the model, taking into account the number of predictors. The standard error of 62,776.97 suggests a relatively low level of residual error in the estimation. The number of observations used for this model is 21.

The significant coefficients for imports and wages highlight the importance of trade and income levels in shaping the demand for industrial products. The intercept is not statistically significant, indicating that it does not contribute meaningfully to explaining the relationship between the variables in the model.

The second equation, which examines the relationship between the volume of industrial products sold and the volume of industrial products produced, imports, and capital investment in industry, also exhibits a strong correlation, with a Multiple R value of 0.996. The R-squared value of 0.9926 indicates that 99.26% of the variation in the volume of industrial products sold can be explained by the independent variables in this model. The adjusted R-squared value of 0.9913 suggests that the model is highly reliable, accounting for the number of predictors used. The standard error is 112,474.97, which is higher than that of the first equation, indicating greater residual variation in the model. The number of observations for this equation is also 21.

The results suggest that both imports and GDP significantly affect industrial production, with imports fostering growth in industrial output and GDP having a counter-intuitive negative impact. In the third equation, which explores the relationship between the volume of industrial products produced and imports, the Multiple R value is 0.9726, suggesting a strong, albeit slightly weaker, correlation compared to the previous two equations. The R-squared value of 0.946 indicates that 94.6% of the variation in industrial production can be explained by GDP and imports. The adjusted R-squared value of 0.9399 further supports the model's robustness, considering the number of predictors used. The standard error of 739,202,662.5 is substantially larger than in the other two equations, suggesting a higher level of variability in the predicted values. The number of observations used in this equation is 21.

All three models show strong explanatory power, with R-squared values exceeding 0.94 for each equation. This suggests that the variables included in each equation are highly relevant to understanding the interconnections between GDP, industrial output, and other economic factors. However, the higher standard error in the third equation signals more variability and indicates areas where further model refinement may be needed.

According to the first equation, GDP (U1) increases by 2.28 units with an increase in the volume of industrial products sold (U2) by one unit, while other variables remain unchanged. This means that an increase in the production and sale of industrial products has a positive effect on GDP. An increase in the export of goods (X1) by one unit leads to a decrease in GDP by 7.17 units. This may indicate that the export structure is dominated by raw material exports, which do not contribute to a significant increase in value added in the country. An increase in the average monthly wage (X3) by one unit increases GDP by 3.59 units.

Table 3

Econometric analysis of the third equation

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95,0%	Upper 95,0%
Intercept	-1163789690,81	372805766,82	-3,12	0,01	-1947025543,06	-380553838,56	-1947025543,06	-380553838,56
y_1	-1154481,29	487209,65	-2,37	0,03	-2178070,78	-130891,81	-2178070,78	-130891,81
x_2	5033,60	1312,23	3,84	0,00	2276,72	7790,49	2276,72	7790,49

Source: Calculated by the authors

This is logical, since an increase in wages stimulates consumption, and therefore the demand for goods and services, which has a positive effect on GDP.

The second equation shows that the volume of industrial products sold (U2) decreases by 7.22 units when the volume of industrial products produced by business entities of various economic activities (U3) increases by one unit. This may mean that part of the produced products is not sold, or there is an overproduction of some types of products. An increase in imports of goods (X2) by one unit leads to an increase in the volume of industrial products sold by 78.9 units. This may indicate that imports are an important source of intermediate products for domestic producers. An increase in capital investments in industry (X4) by one unit leads to a slight increase in the volume of industrial products sold. This may indicate that investments have not yet had their full effect or that there are other constraints to production growth.

According to the third equation, the volume of industrial output produced by business entities of various economic activities (U3) decreases by 1,154,481.29 units with an increase in GDP (U1) by one unit. This may indicate that the structure of the economy is changing, and the share of industry in GDP is decreasing. An increase in imports of goods (X2) by one unit leads to an increase in the volume of industrial output by 5,033.6 units. This confirms the conclusion that imports are an important source of intermediate products.

The findings of this study provide important insights into the factors driving Ukraine's economic growth. The negative relationship between GDP and exports suggests that Ukraine's export sector is primarily composed of raw materials, which offer limited value-added contributions to the national economy. To promote more sustainable economic growth, Ukraine may need to shift its export strategy towards higher-value-added products and diversify its industrial base.

The positive relationship between industrial output and wages aligns with the theoretical expectation that higher wages stimulate domestic demand, which in turn boosts industrial production. Additionally, the positive effect of capital investment on industrial output underscores the importance of continued investment in infrastructure and technological advancement to enhance production efficiency and competitiveness.

The results also emphasize the critical role of imports in supporting Ukraine's industrial sector. Imports provide vital intermediate goods that enable domestic production, suggesting that an open trade policy that facilitates the flow of goods and services is essential for sustaining industrial output.

4. Conclusions

This study provides an empirical analysis of the economic development of Ukraine from 2001 to 2021, using a structural simultaneous model to explore the complex relationships between key economic variables. Our findings highlight the significant roles played by industrial output, trade, wages, and capital investments in shaping the country's economic growth, as measured by Gross Domestic Product (GDP). The model confirms that industrial production and exports are critical drivers of GDP, while the impact of imports and wages also plays a crucial role in determining economic performance.

One of the key findings of this study is the negative relationship between GDP and exports of goods, which may be explained by the structure of Ukraine's export market, where raw material exports dominate, limiting the value added to the economy. In contrast, both higher wages and increased capital investments have positive effects on GDP, reinforcing the notion that investment in human capital and infrastructure can stimulate economic growth. Furthermore, the analysis reveals that imports have a significant role in supporting industrial production, suggesting that trade and international integration are vital for Ukraine's manufacturing sector.

The results of the structural model offer valuable insights for policymakers, indicating the need for a more balanced export strategy that shifts towards higher value-added products, alongside efforts to promote domestic industrial production through increased investment and improved wage structures. Additionally, the positive effect of imports on industrial output suggests that maintaining a competitive and open trade policy could further support Ukraine's economic growth by providing access to essential inputs and promoting technological advancements.

However, the study also highlights some limitations, including the need for further investigation into the structural changes in Ukraine's economy over time and the potential long-term effects of capital investments on industrial productivity. Future research could expand this model by incorporating additional variables such as technological innovation, labor force quality, and external economic factors, as well as by exploring the impact of political instability and economic reforms on the dynamics of economic development.

In conclusion, the empirical model developed in this paper provides a comprehensive understanding of the economic forces at play in Ukraine's development. It offers a valuable framework for analyzing the interdependencies among key economic factors and can serve as a basis for future research aimed at improving the country's economic policy decisions.

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СТРУКТУРНА МОДЕЛЬ ЕКОНОМІКИ УКРАЇНИ: ВЗАЄМОЗВ'ЯЗОК МІЖ ВВП ТА ПРОМИСЛОВІСТЮ

Анотація. *Дослідження полягає в емпіричному аналізі економічного розвитку України із використанням структурної моделі системи одночасних рівнянь для дослідження взаємодії між ключовими економічними змінними. У дослідженні виділено три результуючих змінні: валовий внутрішній продукт (ВВП), обсяг проданої промислової продукції та обсяг виробленої промислової продукції. Результуючі змінні залежать від чотирьох факторних змінних: експорт товарів, імпорт товарів, середня місячна зарплата та капітальні інвестиції в промисловість. Модель розроблена для кількісного оцінювання того, як ці фактори впливають на економічні показники України, з особливим акцентом на ролі промислового виробництва в економіці країни. За допомогою трьох структурних рівнянь у статті досліджено взаємні залежності між цими економічними індикаторами та підтверджено, що промислове виробництво, заробітна плата та експорт відіграють значну роль у стимулюванні зростання ВВП. Крім того, імпорт сприяє промисловому виробництву та продажам, що свідчить про те, що він є життєво важливими ресурсами для внутрішнього виробництва. Результати показують, що в той час як експорт має негативний вплив на ВВП, ймовірно, через домінування експорту сировини, вищі зарплати та капітальні інвестиції позитивно впливають на економічне зростання. Усі параметри моделі статистично значущі із 95% рівні достовірності, а висновки дають цінну інформацію для політиків, які прагнуть посилити промислове зростання та оптимізувати торгові та інвестиційні стратегії для сталого економічного розвитку в Україні.*

Ключові слова: *економічний розвиток, структурне моделювання, макроекономічне моделювання, економічне зростання, ВВП, промислове виробництво, економічна політика, економічні показники, промислове виробництво, експорт, імпорт, капітальні інвестиції, модель.*