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# THRESHOLD EFFECTS OF FOREIGN TRADE AND LABOR PRODUCTIVITY: AN EMPIRICAL STUDY

**Background.** ***This article investigates the non-linear impact of export and import activities on the labor productivity of Ukrainian SMEs under conditions of extreme macroeconomic volatility (2017–2024), encompassing the COVID-19 pandemic and the full-scale war. The study identifies structural breakpoints that distinguish early-stage internationalization from integrated operations amidst wartime disruptions.***

**Methods.** ***The research utilizes a panel data threshold regression methodology to endogenously identify structural breaks. The model accounts for individual fixed effects to control for unobserved firm-level heterogeneity. The study accounts for limitations arising from the small sample size (30 observations) and the impact of forced reclassification of firms by size due to mass labor migration and mobilization during the full-scale invasion.***

**Results.** ***The empirical analysis indicates that the relationship between productivity and personnel costs is moderated by international intensity. For the export model ($R^2 = 0.539$), a threshold of 7.5% in total sales was identified. Below this point, enterprises experience an initial high-return regime with high marginal returns ($\beta_1 = 833.72$). Beyond this threshold, returns diminish ($\beta_2 = 726.85$), suggesting that further growth requires deep technological integration. In the import model ($R^2 = 0.508$), a systemic threshold of 17.5% was identified. A technology-driven productivity premium was identified in the second regime, where labor efficiency increases by 25%, driven by the integration of foreign high-tech intermediate goods into production processes.***

**Conclusions.** ***Findings suggest a shift in economic policy toward targeted interventions. For enterprises below the 7.5% export threshold, support should focus on lowering entry barriers via Export Credit Agencies. For those exceeding this limit, policy should shift toward R&D incentives. Regarding imports, the study advocates for the selective liberalization of customs barriers for high-tech resources, facilitating the crossing of the 17.5% efficiency barrier. These recommendations provide policy directions for strengthening economic resilience amidst the full-scale war.***

**Keywords:** ***labor productivity, threshold regression, exports, imports, systemic threshold, import dependence, martial law.***

## Background

In the current context of global instability and the economic transformation of Ukraine, facilitating export expansion alongside the strategic integration of high-tech imports is a strategic priority for restoring industrial capacity and ensuring long-term economic recovery. However, a mere increase in trade volumes does not always lead to a proportional rise in firm efficiency. A key question for economic policy and corporate management is identifying the systemic threshold beyond which international trade activity begins to qualitatively alter a firm's internal economic processes – specifically the mechanism through which labor costs translate into productivity gains. Understanding these non-linear effects allows for the differentiation of support measures based on a firm's level of international engagement.

Participation in global value chains mandates that enterprises invest in high-skilled personnel and innovative solutions to overcome international competitive pressures. Yet, empirical data suggest this relationship is non-linear. Small and medium-sized enterprises (SMEs) face high entry barriers, and economies of scale emerge only after reaching certain operational volumes. This article seeks to identify structural breaks in the panel data of Ukrainian enterprises from 2017 to 2024. The use of threshold regression allows not only to confirm the impact of exports and imports on performance but also to mathematically determine the critical share of export sales and imported inputs that divide enterprises into distinct regimes.

***The purpose*** of this study is to identify and quantify the critical threshold levels of export and import intensity for Ukrainian enterprises and to evaluate how crossing these thresholds alters the marginal returns of labor costs on overall productivity.

***Literature review.*** Hansen (1999) proposed a methodology for estimating threshold effects in panel data, allowing for the endogenous determination of structural break points. The author demonstrates that relationships between economic indicators often change abruptly when a specific critical value of a threshold variable is reached. The theoretical foundation for sample splitting and threshold parameter estimation was further detailed in Hansen (2000). He developed an asymptotic theory for threshold models that allows researchers to identify the structural break point by minimizing the sum of squared residuals (SSR) and to evaluate the statistical significance of the resulting regimes. This approach is critical for our study as it provides a mathematical basis for confirming distinct behavioral regimes of firms based on their involvement in international trade.

The methodological framework for evaluating threshold effects in panel data was expanded by Wang (2015), who provided tools for implementing fixed-effects models. The author showed that this approach objectively identifies threshold values through SSR minimization while controlling unobserved heterogeneity among units. This creates a robust foundation for analyzing changes in the marginal

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productivity of production factors across different operational regimes.

Numerous scholars have utilized the Hansen (1999) threshold regression model in their research. Melitz (2003) employed a model suggesting that only the most productive firms become exporters due to high fixed entry costs, substantiating the existence of a "systemic barrier" related to labor productivity. Khan and Senhadji (2001) applied Hansen's methodology to panel data from 140 countries to find the point at which inflation begins to hinder the economy. They identified clear thresholds: 1–3 percent for industrial countries and 11–12 percent for developing countries.

Yeh et al. (2010) used threshold modeling to investigate how Research and Development (R&D) spending drives company profits. Using R&D intensity as the threshold, the study showed a minimum investment requirement below which no effect exists, and an upper limit beyond which excessive R&D spending yields no additional value. Law and Singh (2014) explored the negative consequences of the overexpansion of private credit, finding that once private credit reaches 88–100 percent of GDP, the financial sector begins to divert resources from the real sector, slowing growth. Minea and Parent (2012) examined the variability of threshold effects associated with public debt, identifying complex non-linearities where the impact of debt on growth became less negative at very high levels (above 115 percent). Similarly, Cecchetti, Mohanty, & Zampolli (2011) analyzed OECD data (1980–2010) and established that debt exceeding 85 percent of GDP acts as a drag on economic growth.

Croi and Diaw (2020) and Ibañez Martín, Rojas and Dabús (2024) show that macroeconomic impacts, such as debt on growth, are inherently non-linear, often shifting at critical thresholds like a reported threshold of 42.32%. These studies suggest that the effectiveness of economic drivers depends on reaching a certain systemic maturity. In the context of transition economies, De Loecker (2007) further demonstrates that this non-linearity extends to international trade, where entering foreign markets generates specific 'learning-by-exporting' productivity gains. Accordingly, it is vital to determine the specific export intensity threshold that catalyzes labor efficiency for Ukrainian firms, serving as a firm-level threshold for productivity gains.

Regarding imports, Amiti and Konings (2007) found that access to high-quality imported inputs and raw materials has a significantly greater impact on productivity than reducing tariffs on final goods. Thus, identifying an import activity threshold is necessary to determine when imported resources reach a volume sufficient to yield productivity gains driven by technology adoption. Kasahara and Rodrigue (2008) also found that using imported components is an important determinant of firm-level productivity growth and stimulates internal modernization. Expanding this line of research with more recent firm-level evidence, Camino-Mogro and Carrillo-Maldonado (2023) examined the causal effect of importing intermediate inputs on firm productivity using panel data for Ecuadorian manufacturing firms (2007–2018), applying an augmented Cobb-Douglas production function. The study confirmed both static and dynamic productivity gains from importing, with the learning-by-importing effect being more pronounced in technologically intensive industries and provided robust evidence of industrial heterogeneity in the productivity returns to import activity. Finally, Bernard and Jensen (2004) substantiated the "self-selection" hypothesis, where high sunk entry costs create a barrier that only highly productive (and usually larger) firms can overcome. This further supports the need to reach a threshold level of systemic export to stabilize economic effects.

Das (2023) applied the Hansen (1999) panel threshold methodology to investigate the non-linear relationship between inflation and economic growth across 20 European countries. The author confirmed the existence of structural breaks, demonstrating that the impact of price instability on GDP dynamics shifts fundamentally once a specific threshold of 4.2% is reached. This study highlights the versatility of the threshold approach in identifying critical limits beyond which macroeconomic factors transition from being growth-enhancing factors to significant developmental constraints.

Mensah, Mensah, and Danquah (2024) applied the fixed-effect panel threshold regression to examine how inflation levels moderate the FDI–growth nexus across Ghana, Nigeria, and South Africa (1982–2020). The study identified two structural breaks: below the first threshold of 7.26%, FDI exerts its strongest growth-enhancing effect, while beyond the second threshold of 16.49%, this beneficial effect diminishes, confirming that macroeconomic stability is a prerequisite for effective absorption of foreign capital.

Given these studies, we consider it appropriate to use the Hansen (1999) methodology to search for a "systemic threshold" – the critical point where international trade activity begins to influence business efficiency in a fundamentally different manner.

***Hypotheses.*** The following hypotheses are tested in this study:

H1: There is a statistically significant threshold for the share of exports (imports) in total sales that separates firms into low-intensity vs high-intensity regimes.

H2: The impact of labor costs on labor productivity differs significantly below and above the threshold and is non-linear.

H3: Crossing the systemic threshold is associated with changes in the marginal returns of labor costs per employee due to shifts in the technological base or management structure.

The postulated null hypothesis (H0) for each of the models states that the relationship between labor productivity and labor costs per employee is linear and uniform across all levels of export and import intensity. Specifically, it assumes that no structural break exists at any threshold value of the export or import share in total sales ($\beta_1 = \beta_2$).

***Data and materials.*** The study utilized statistical data on the volume of products (goods, services) sold and manufactured, labor costs, number of employees, and export/import volumes for enterprises of various sizes for the period 2017–2024. The total number of observations for each indicator is 30 (representing four size classes of enterprises over 8 years, excluding two outliers identified as anomalous observations that materially affected parameter estimates).

**Methods**

To test the research hypotheses, we applied the panel data threshold regression methodology proposed by Hansen (1999). This approach allows for the endogenous determination of threshold values by minimizing the sum of squared residuals (SSR), effectively identifying structural breaks in the data.

Model Specification

The analysis is based on panel data categorized into four enterprise size classes based on the number of employees for the period 2017–2024 (30 observations):

- Class 1: Up to 9 employees;
- Class 2: 10–49 employees;
- Class 3: 50–250 employees;
- Class 4: More than 250 employees.

The structural relationship for the systemic export threshold is modeled as:

$$Y_{it} = \beta_1^{\exp} LNX_{it} I(q_{it}^{\exp} \le \gamma_{\exp}) + \\ +\beta_2^{\exp} LNX_{it} I(q_{it}^{\exp} > \gamma_{\exp}) + \mu_i^{\exp} + \varepsilon_{it}^{\exp}. \quad (1)$$

The structural relationship for the systemic import threshold is modeled as:

$$Y_{it} = \beta_1^{imp} LNX_{it} I(q_{it}^{imp} \le \gamma_{imp}) + \\ +\beta_2^{imp} LNX_{it} I(q_{it}^{imp} > \gamma_{imp}) + \mu_i^{imp} + \varepsilon_{it}^{imp}, \quad (2)$$

where $Y_{it}$ – is labor productivity (dependent variable); $X_{it}$ – is labor costs per employee (explanatory variable); $q_{it}^{\exp}$, $q_{it}^{imp}$ – are the threshold variables (export and import shares in total sales, respectively); $\gamma_{\exp}$, $\gamma_{imp}$ – are the estimated thre shold values; I(•) – is the indicator function; $\beta_1^{\exp}$, $\beta_2^{\exp}$, $\beta_1^{imp}$, $\beta_2^{imp}$ – are the regime-specific regression coefficients; $\mu_i^{\exp}$, $\mu_i^{imp}$ – represents fixed effects; $\varepsilon_{it}^{\exp}$, $\varepsilon_{it}^{imp}$ – is the error term; *i* – denotes the enterprise size class (*i* = 1, 2, …, 4); *t* – denotes the time period (8 time periods).

*Variable definitions and operationalization*

Labor productivity Yit is calculated in thousands of Ukrainian Hryvnias (UAH) as the total output volume divided by the number of employees. It serves as the primary metric for economic efficiency. We examine how this indicator responds to changes in labor costs across different trade regimes.

Labor costs per employee Xit are defined as total personnel expenses divided by the workforce size (in thousands of UAH). This variable represents investment in human capital, and the model estimates the marginal return on these expenditures.

Export/Import Intensity $q_{it}^{\exp}$, $q_{it}^{imp}$ is the ratio of export or import volume to total sales, expressed as a percentage. This parameter serves as the threshold variable determining regime shifts. The model identifies a structural break relative to this variable to distinguish between initial and integrated international engagement.

Fixed Effects $\mu_i^{\exp}$, $\mu_i^{imp}$ account for unobserved individual heterogeneity – constant differences between enterprise classes, such as industry-specific characteristics or baseline technological levels, that remain stable over time.

The Error Term $\varepsilon_{it}^{\exp}$, $\varepsilon_{it}^{imp}$ represents the stochastic component (white noise), capturing the influence of exogenous factors not explicitly included in the model.

Control for Confounding Factors. The study period (2017–2024) encompasses two major macroeconomic shocks: the COVID-19 pandemic (2020–2021) and the full-scale military invasion of Ukraine (2022–2024). Their influence is partially addressed through the fixed-effects specification, which absorbs time-invariant heterogeneity across enterprise size classes. Year-specific shocks common to all groups are controlled through the panel structure of the data. However, given the aggregate nature of the data, full causal isolation of these shocks from trade-driven productivity effects is not feasible without additional regression instruments. This constitutes a limitation of the study, discussed further in the Discussion section.

**Results**

*Baseline Data for Export and Import Threshold Regression Models*

Threshold regression models allow for an analysis of how export and import shares in total sales influence labor productivity and help identify enterprises operating above the estimated threshold, which may be associated with greater resilience.

Table 1 presents the descriptive statistics for the variables used in the export and import threshold regression models, based on 30 observations covering enterprise activities from 2017 to 2024.

***Table 1***

**Labor-Cost Efficiency Indicators in Exporting and Importing Enterprises**

| Variable | Notation | Unit of Measurement | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|---|
| Labor Productivity | $Y_{it}$ | thousand UAH / person | 1,227.69 | 391.06 | 620.55 | 1,981.31 |
| Labor Costs | $X_{it}$ | thousand UAH / person | 126.43 | 63.81 | 33.57 | 296.45 |
| Export Share in Total Sales | $q_{it}^{\exp}$ | % | 9.68 | 5.48 | 2.61 | 20.89 |
| Import Share in Total Sales | $q_{it}^{imp}$ | % | 14.82 | 3.68 | 9.31 | 24.95 |

*Note.* Calculated by the authors based on data from the State Statistics Service of Ukraine based on export of goods, import of goods, volume of sold products, labor costs, and number of employees. (State Statistics Service of Ukraine, n. d.-a, n. d.-b, n. d.-c, n. d.-e, n. d.-f).

Based on the analysis of Table 1, the mean labor productivity is 1,227.69 thousand UAH per person. Significant data variability is observed, with a coefficient of variation of 31.9 percent (391.06 / 1,227.69 × 100 percent). This indicates heterogeneity among enterprise classes regarding their labor productivity levels.

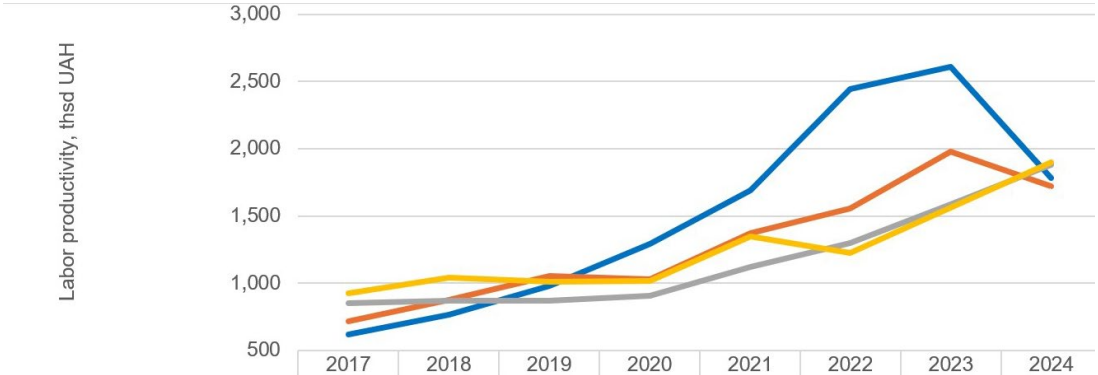
The average labor costs per employee amount to 126.43 thousand UAH per person. Values range from 33.57 to 296.45 thousand UAH, with a coefficient of variation of 50.5 percent (63.81 / 126.43 × 100 percent). This reflects varying capacities for labor compensation across enterprises of different size classes.

Figure 1 illustrates the dynamics of labor productivity across Ukrainian enterprises categorized by the number of employees.

Figure 1 illustrates how business scale influences the ability to respond to crisis conditions and adapt under different levels of international trade activity (ITA) thresholds. The data reveal distinct adjustment patterns across different enterprise groups under martial law. The micro-business sector (up to 9 employees) exhibited the highest volatility. During 2022–2023, this group experienced a sharp increase in productivity to 2,609.95 thousand UAH per person, significantly outpacing general market trends. This sharp increase is likely anomalous, driven by statistical accounting specifics and personnel reductions that artificially inflated the per-capita figure. Consequently, these extreme 2022–2023 values for micro-enterprises were classified as outliers and excluded from subsequent regression modeling to ensure the robustness of the results. The sharp decline to 1,784.46 thousand UAH in 2024 confirms the instability of previous trends in this segment and a return toward a more stable level.

In contrast, large enterprises (250+ employees) demonstrated high resilience, regained the highest productivity level in 2024 with a figure of 1,897.61 thousand UAH per person, consistent with the hypothesis that the advantages of economies of scale during crises. The

medium-sized enterprise group (50–249 employees) is characterized by the most stable upward trajectory, reaching 1,877.38 thousand UAH per person in 2024 and effectively approaching the productivity levels of large enterprises. Small enterprises (10–49 employees) followed a parabolic trend similar to micro-businesses but with lower amplitude: after a peak in 2023 (1,981.31 thousand UAH), a correction to 1,723.98 thousand UAH occurred, possibly indicating the exhaustion of short-term adjustment capacity.




| | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
|---|---|---|---|---|---|---|---|---|
| Up to 9 employees | 620.55 | 765.59 | 981.42 | 1,289.15 | 1,689.34 | 2,445.65 | 2,609.95 | 1,784.46 |
| 10–49 employees | 717.93 | 874.84 | 1,055.46 | 1,027.03 | 1,372.29 | 1,553.17 | 1,981.31 | 1,723.98 |
| 50–249 employees | 852.15 | 869.17 | 868.35 | 903.15 | 1,117.56 | 1,296.77 | 1,588.91 | 1,877.38 |
| 250 employees and more | 922.75 | 1,038.67 | 1,011.70 | 1,015.92 | 1,347.11 | 1,223.31 | 1,563.78 | 1,897.61 |

**Fig. 1. Dynamics of labor productivity by enterprise size classes (2017–2024), thsd UAH per employee**
*Note.* Calculated by the authors based on data from the State Statistics Service of Ukraine based on the volume of sold products and the number of employees of economic entities (State Statistics Service of Ukraine, n. d.-c, n. d.-f).

*Identification of Export and Import Thresholds*

The threshold estimation proceeded in three steps:

1. Threshold Search: A sequential grid search across export share values (from 2.5 percent to 22.5 percent in 2.5 percentage-point increments) and import share values (from 7.5 percent to 25 percent with a 2.5 percent increment) to identify the global minimum of the Sum of Squared Residuals.

2. Statistical Significance Testing: Verification of model significance using F-statistics and P-value analysis for each identified regime.

3. Comparative Analysis: Evaluation of regression coefficients to interpret shifts in the marginal effect of labor costs on productivity across different regimes of export and import activity.

To ensure the statistical reliability of the threshold regression model, the optimal threshold values ($\gamma_{exp}$, $\gamma_{imp}$) were identified based on the sum of squared residuals (SSR) minimization criterion.

A sequence of regression models was constructed for various export share values (ranging from 2.5 percent to 22.5 percent), with the SSR calculated for each iteration. Figure 2 illustrates the results of this analysis, identifying the optimal export threshold by minimizing the sum of squared residuals according to Model (1).

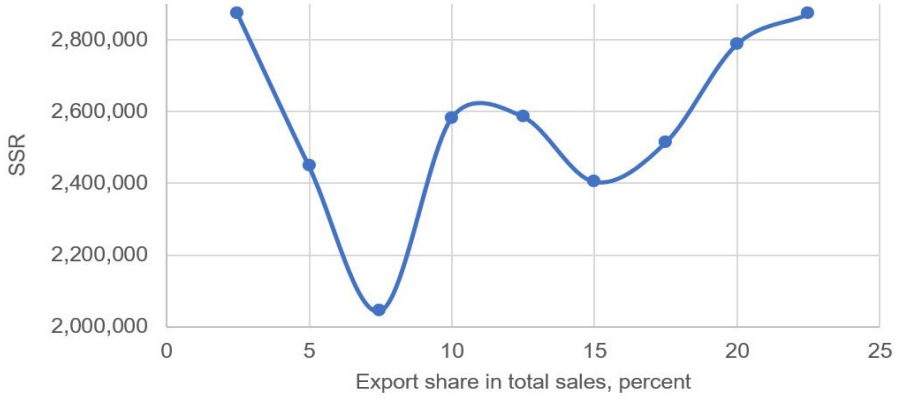



**Fig. 2. SSR Minimization Plot for Identifying the Systemic Export Threshold**
*Note.* Calculated by the authors based on data from the State Statistics Service of Ukraine, based on export of goods, volume of sold products, volume of manufactured products, labor costs, and number of employees (State Statistics Service of Ukraine, n. d.-a, n. d.-c, n. d.-d, n. d.-e, n. d.-f).

Figure 2 illustrates the non-linear nature of the SSR objective function, which reaches its lowest value at an export share of 7.5 percent. This indicates a shift between regimes of enterprises upon reaching the 7.5 percent export threshold.

Similarly, a sequence of regression models was constructed for various import share values (ranging from 7.5 percent to 25 percent), with the SSR calculated for each iteration. Figure 3 illustrates the results of this analysis, identifying the optimal import threshold by minimizing the sum of squared residuals according to Model (2).

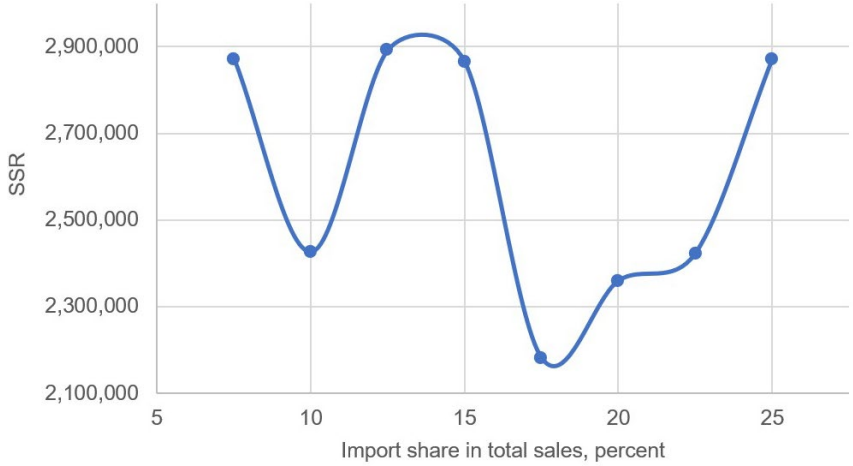



**Fig. 3. SSR Minimization Plot for Identifying the Systemic Import Threshold**

*Note.* Calculated by the authors based on data from the State Statistics Service of Ukraine, based on the import of goods, volume of sold products, volume of manufactured products, labor costs, and number of employees (State Statistics Service of Ukraine, n. d.-b, n. d.-c, n. d.-d, n. d.-e, n. d.-f).

The analysis of the Sum of Squared Residuals (SSR) minimization function, presented in Figure 3, empirically identifies evidence of a structural shift occurring at an import share of 17.5 percent. This value is identified as the threshold at which a change in the economic regime occurs, where the nature of the impact of import flows on an enterprise's labor productivity changes.

In contrast to the export model, where the minimum was distinct and singular, the SSR plot for imports demonstrates significant volatility with several local extrema (specifically, a local minimum at the 10 percent mark). This non-linear dynamic suggests a more complex process of cumulative effects from technology imports, with productivity gains becoming more pronounced after the 17.5 percent threshold is reached.

Table 2 presents the reliability testing results for the export and import threshold regression parameters.

***Table 2***

**Summary of threshold regression diagnostic results**

| Indicator / Variable | Export threshold regression model | Import threshold regression model |
|---|---|---|
| Systemic Threshold ($\gamma$), percent | 7.5% | 17.5% |
| Constant term | –2,381.63 | –491.90 |
| Regime 1 Coefficients: Export ($q_{it}^{\exp} \leq \gamma_{\exp}$) Import ($q_{it}^{imp} \leq \gamma_{imp}$) | 833.72 | 349.32 |
| Regime 2 Coefficients: Export ($q_{it}^{\exp} > \gamma_{\exp}$) Import ($q_{it}^{imp} > \gamma_{imp}$) | 726.85 | 436.28 |
| R-squared ($R^2$) | 0.539 | 0.508 |
| *F*-statistic | 15.78 | 13.95 |
| *p*-value | $2.89 \times 10^{-5}$ | $6.89 \times 10^{-5}$ |
| Number of Observations | 30 | 30 |

*Note.* Calculated by the authors based on data from the State Statistics Service of Ukraine, based on export of goods, import of goods, volume of sold products, volume of manufactured products, labor costs, and number of employees (State Statistics Service of Ukraine, n. d.- a, n. d.-b, n. d.-c, n. d.-d, n. d.-e, n. d.-f).

The results indicate that the systemic export threshold is 7.5 percent. With this sample split, the model demonstrates the highest explanatory power ($R^2$ = 0.539), supporting the choice of this threshold for further analysis. The import model shows a lower explanatory power ($R^2$ = 0.508), indicating a less stable relationship than in the case of exports. Both models are statistically significant ($p$ < 0,001), justifying the chosen thresholds for Ukrainian enterprises during the 2017–2024 period.

The threshold regression estimation revealed a structural break in the relationship between labor costs and labor productivity depending on the level of export orientation. Diminishing marginal returns is observed, whereby crossing the 7.5 percent threshold causes the return coefficient to decrease from 833.72 to 726.85.

*Regime 1* ($\beta_1^{\exp}$= 833.72) indicates that for enterprises with an export share up to 7.5 percent, there is a high marginal return on labor costs; increasing these costs has a more pronounced positive impact on labor productivity. An increase in labor costs per employee of 1 thousand UAH is associated with an average labor productivity growth of 833.72 thousand UAH. This is explained by the fact that in the initial stages of market entry, labor costs and the intellectual component are the primary resources for overcoming entry barriers. Labor costs play a more pronounced role in early-stage productivity dynamics. Each unit of investment in personnel yields the greatest productivity gain, which is consistent with the "learning-by-exporting" hypothesis, though the observed pattern may also reflect other firm-level factors, such as baseline technological capacity or managerial quality, not explicitly captured in the model.

*Regime 2* ( $\beta_2^{\exp}$= 726.85) shows that after crossing the 7.5 percent export share threshold, marginal returns on labor costs decrease. An increase in labor costs per employee of 1 thousand UAH leads to a productivity increase of only 726.85 thousand UAH. This indicates a shift in dominant growth factors toward technological and organizational drivers, reducing the relative role of purely wage-based incentives. This also supports the findings of

Bernard and Jensen (2004), who argue that scale effects are decisive; the identified 7.5 percent threshold reflects a transition consistent with the recovery of entry costs associated with export market participation.

Figure 4 visually demonstrates the change in labor productivity elasticity when crossing the 7.5 percent systemic export threshold. Regime 1 shows the relationship between labor productivity and export share before reaching the 7.5 percent threshold, while Regime 2 shows it after the threshold is reached.

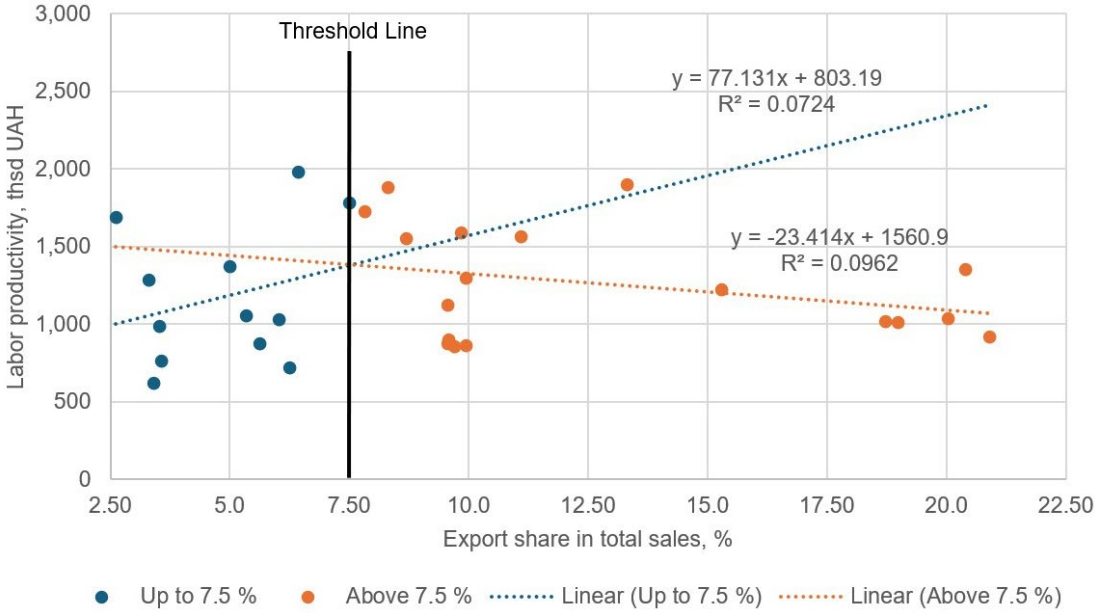



**Fig. 4. Regime differences in the relationship between labor productivity and export share at the 7.5 percent threshold**
*Note.* Calculated by the authors based on data from the State Statistics Service of Ukraine, based on export of goods, volume of sold products, volume of manufactured products, labor costs, and number of employees (State Statistics Service of Ukraine, n. d.-a, n. d.-c, n. d.-d, n. d.-e, n. d.-f).

The low $R^2$ values in the separate regime plots (0.0724 and 0.0962, respectively, in Fig. 4) are attributed to the high level of sample heterogeneity, which encompasses various enterprise size classes. This visualization represents only a pairwise linear relationship, since the plots represent bivariate relationships that exclude labor costs as a control variable. The inclusion of labor costs in the multifactor regression model (1) accounts for the higher explanatory power of the full model ($R^2 = 0.539$).

The residual variability in the plot suggests that the export share alone is not the sole determinant of labor productivity; however, it defines the economic "regime" of operations. The scatter plot visualization (Figure 4) indicates that both regimes in export activity exhibit divergent correlations, with the 7.5 percent threshold dividing the trajectory into a "starting momentum" phase and a "diminishing marginal returns" phase.

The "*Starting Momentum*" Phase (Regime 1): described by the equation y = 77.131x + 803.19, indicates the stimulating effect of initial export expansion. The "*Diminishing Marginal Returns*" Phase (Regime 2): described by the equation y = –3.414x + 1,560.9, suggests that excessive export concentration without corresponding technological support leads to diminishing returns.

The high density of observations around the mean export share of 9.68 percent (see Table 1), which exceeds the 7.5 percent threshold, suggests that the majority of enterprises in the sample have already transitioned beyond the initial acceleration phase and are operating within a "marginal saturation" regime. While average productivity in this zone remains high (1,227.69 thsd UAH/person), the negative trend suggests these firms have hit an "efficiency ceiling," where further increases in physical export volumes no longer yield additional returns from human capital.

The mechanism through which imports affect labor productivity differs fundamentally from that of exports. Threshold analysis results confirm that the relationship between labor costs and labor productivity is non-linear and depends on import intensity. In the import model, an amplification effect is observed: upon crossing the 17.5 percent threshold, the marginal return coefficient increases from 349.32 to 436.28.

- Regime 1 ( $\beta_1^{imp}$= 349.32): At an import share below the systemic threshold (up to 17.5 percent), a 1 thousand UAH increase in labor costs per employee leads to an average productivity growth of 349.32 thousand UAH. While rising wages enhance motivation, growth is constrained by the existing technological level.
- Regime 2 ( $\beta_2^{imp}$= 436.28): When the import share exceeds 17.5 percent, the marginal return to each unit of labor cost increases by approximately 25 percent. This pattern is consistent with the hypothesis that access to foreign technologies or raw materials enhances labor efficiency – technology-driven productivity premium. However, since the technological level is not directly measured in the model, the observed productivity gain may also reflect other factors associated with high import intensity, such as firm size, market selection, or sectoral composition.

Figure 5 demonstrates the change in slope (elasticity) of labor productivity when crossing the systemic import threshold. Regime 1 illustrates the dependency before reaching the 17.5 percent threshold, while Regime 2 illustrates it after the threshold is surpassed.

In the first regime (import share < 17.5 percent), a distinct negative trend is observed (y = –16.2x + 1,355.2). This represents a "cost-intensive import" zone, where fragmented purchases of foreign resources create logistic and currency pressures that are not yet offset by gains in efficiency.

However, after crossing the 17.5 percent threshold, the trend reverses, becoming upward-sloping (y = 14.7x + 1407). This indicates a transition into a "technological modernization" regime. Thus, only import levels exceeding the systemic threshold of 17.5 percent enable meaningful integration of modern technologies. This integration offsets transaction costs and generates measurable labor productivity gains.

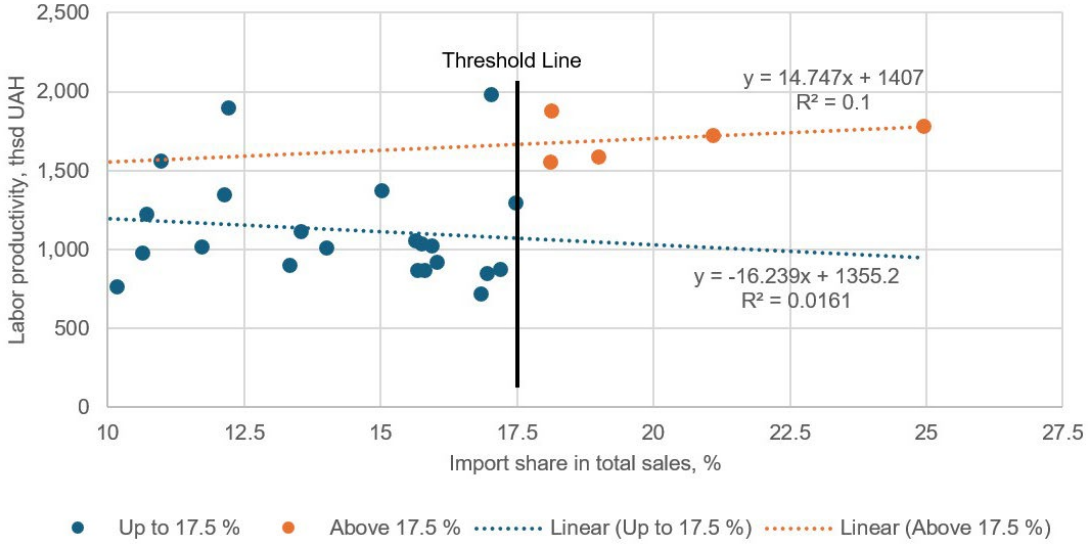



**Fig. 5. Structural shift in the relationship between labor productivity and enterprise import share at the 17.5 percent systemic threshold**

*Note.* Calculated by the authors based on data from the State Statistics Service of Ukraine, based on import of goods, volume of sold products, volume of manufactured products, labor costs, and number of employees (State Statistics Service of Ukraine, n. d.-b, n. d.-c, n. d.-d, n. d.-e, n. d.-f).

## Discussion and conclusions

Pryhara and Yarosh-Dmytrenko (2023) analyze the challenges faced by Ukrainian businesses during the war, specifically highlighting logistical disruptions and currency instability. This context helps account for the observed productivity constraints at low import shares (below 17.5 percent): the transaction costs and security risks outweigh the marginal technological benefits.

In their study, Fedulova and Stadnyk (2025) examine the barriers small and medium-sized enterprises (SMEs) encounter when engaging in international trade activity. Our modeling results suggest that these barriers exert a detrimental effect primarily in the context of fragmented import activity. Once systemic import levels are achieved, productivity formation mechanisms shift toward technologically driven factors.

*Comparison of export and import threshold regression models*

A comparison of the regime coefficients across the export and import threshold models reveals that the labor productivity returns to labor costs are approximately twice as large in the export model as in the import model. This suggests that in Ukraine, export orientation is associated with a stronger marginal effect on labor productivity than import activity.

Table 3 summarizes the research findings and provides a comparative characterization of the export and import threshold regression models. A fundamental difference was identified in the mechanisms through which external vectors influence enterprise labor productivity. Specifically, while exports demonstrate a "diminishing returns" effect, imports follow the law of "increasing returns to scale".

***Table 3***

**Comparative analysis of export and import threshold effects**

| Feature | Export Model (7.5 percent Threshold) | Import Model (17.5 percent Threshold) |
|---|---|---|
| Operational Logic | Trend reversal: a shift from a steeply ascending to a descending trajectory; returns on labor costs decrease from 834 to 727 | Trend reversal: a shift from a descending to an ascending trajectory; returns on labor costs increase from 349 to 436 |
| Economic Implication | Low-base effect: Initial entry into foreign markets yields rapid efficiency gains, which subsequently plateau or diminish without technological upgrades | Critical mass effect: A transition from "import as a burden" (transaction costs) to "import as a driver" (technological rent) |
| Critical Limit | 7.5 percent – The limit of extensive growth (the "efficiency ceiling" in the absence of innovation) | 17.5 percent – The threshold for systemic break-even and technological modernization |

*Note.* Calculated by the authors based on data from the State Statistics Service of Ukraine, based on export of goods, import of goods, volume of sold products, volume of manufactured products, labor costs, and number of employees (State Statistics Service of Ukraine, n. d.-a, n. d.-b, n. d.-c, n. d.-d, n. d.-e, n. d.-f).

It has been demonstrated that fundamentally different mechanisms govern the impact of international trade activity (ITA) on labor productivity for Ukrainian enterprises. While export activity exhibits a high-return initial phase followed by a structural decline upon reaching the 7.5 percent threshold – reflecting the exhaustion of extensive growth reserves – import activity requires the accumulation of a critical mass of foreign inputs – exceeding 17.5 percent – to offset the burden of transaction costs. Findings reveal that the 17.5 percent threshold serves as a bifurcation point, beyond which imports are transformed into a systemic driver of technological acceleration, enabling enterprises to achieve productivity gains that outweigh the risks associated with external shocks.

Our empirical findings regarding the 7.5 percent export threshold provide a nuanced addition to the 'self-selection' hypothesis established by Bernard and Jensen (2004). While they argue that high productivity is a prerequisite for entering foreign markets, our results suggest that once this entry occurs, the 'learning-by-exporting' effect described by De Loecker (2007) is most potent only during the 'starting momentum' phase.

In contrast to the linear productivity growth often associated with trade liberalization (e.g., Amiti and Konings (2007)), our study identifies a critical 'saturation' point at 7.5 percent export share, where marginal returns begin to diminish. This structural break suggests that for Ukrainian enterprises, human capital and wage incentives, which are key drivers initially, eventually hit an 'efficiency ceiling'.

Furthermore, the identified 17.5 percent import threshold supports the technology-driven productivity premium theory of Kasahara and Rodrigue (2008), suggesting that imported inputs function as a systemic growth driver only after reaching a critical mass that can offset the transaction costs and logistical risks typical of a wartime economy.

*Research limitations*

The proposed methodological approach and the resulting analysis have several limitations that should be considered when interpreting the findings.

First, the study relies on aggregated secondary data from the State Statistics Service of Ukraine, which limits the ability to analyze heterogeneity within each enterprise size class. Although the identified intergroup variability is sufficient for achieving the research objectives at the macro level, there remains a risk of "ecological fallacy", where patterns identified for aggregate categories may not extrapolate to individual firms. Furthermore, data for 2023–2024 may be subject to further revision, which is a standard constraint inherent to real-time analysis conducted under conditions of full-scale war.

Second, the empirical analysis is subject to certain statistical constraints, specifically a relatively small sample size of 30 observations and comparatively low coefficients of determination ($R^2$=0.539 for the export model and $R^2$=0.508 for the import model). These values indicate that while the identified trends are statistically significant, a substantial portion of labor productivity variance remains unexplained by the selected variables, pointing to the influence of unobserved factors such as firm-specific managerial quality or unobserved government support.

Third, the official statistics do not fully capture informal trade volumes, which may have increased under wartime conditions, nor do they account for enterprises located in temporarily occupied territories or those whose productive assets were destroyed in combat zones. The observed dynamics may therefore potentially overstate the overall resilience of certain economic sectors. Additionally, the model can identify the contribution of specific factors, but cannot mathematically isolate the impact of energy infrastructure destruction from shifts in EU market demand without further regression instruments.

Fourth, during the period of the full-scale invasion (2022–2024), many enterprises underwent significant size reclassification due to mobilization and large-scale labor migration. Such reclassification may reflect workforce reductions driven by mobilization or displacement rather than deliberate changes in strategic positioning.

Finally, the study faces endogeneity challenges. While we examine how productivity drives international engagement, reverse causality – where successful exporting enables economies of scale that further raise productivity – cannot be excluded. Due to the absence of direct technological indicators, the identified "learning-by-exporting" effect and technology-driven productivity premium should be interpreted as patterns consistent with the data rather than strictly established causal mechanisms.

This study empirically demonstrates the non-linear, discrete nature of ITA's impact on the labor productivity of Ukrainian enterprises from 2017 to 2024. It is established that this impact is not static but undergoes a fundamental shift upon reaching specific critical values (bifurcation points), thereby redirecting the enterprise's productivity trajectory.

- *Testing H1: Hypothesis Confirmed***.** The threshold analysis empirically identifies statistically significant structural breaks for both export and import intensities. These results confirm that the mechanism by which labor costs are converted into productivity gains undergoes a fundamental shift once specific thresholds are reached. Specifically, a systemic export threshold of 7.5% marks the transition from a high-return growth phase to marginal saturation. For imports, a technological threshold of 17.5% signifies a transition toward enhanced labor productivity.
- *Testing H2: Hypothesis Confirmed.* The study found that for exports, the highest elasticity of labor productivity relative to labor costs occurs in the first regime ($\beta_1^{\exp}$= 833.72), while after crossing the threshold, the return coefficient declines to $\beta_2^{\exp}$ = 726.85. Crossing the systemic import threshold is accompanied by a 25 percent increase in marginal labor efficiency (from $\beta_1^{imp}$= 349.32 to $\beta_2^{imp}$= 436.28), confirming a technology-driven productivity premium from utilizing foreign resources. This suggests that identical wage policies yield varying levels of effectiveness depending on a firm's degree of integration into foreign markets, refuting the assumption of a linear and stable impact of wages on productivity.
- *Testing H3: Hypothesis Confirmed.* Empirical results demonstrate a shift in the marginal return on labor costs after reaching systemic thresholds, consistent with the assumption of structural shifts in production and management models. For exports, crossing the 7.5 percent threshold changes the nature of the return from increasing to diminishing. This indicates that existing management structures and production capacities reach their limits during the "starting momentum" phase. Further scaling without qualitative upgrades results in diminishing returns to labor investment. Conversely, crossing the 17.5 percent import threshold triggers a structural shift, whereby the accumulation of a critical mass of foreign inputs sharply raises the marginal return per worker, transforming import expenditure from a cost burden into a driver of productivity-led growth. Notably, variables directly reflecting technological levels or organizational innovations were not explicitly used in the model. Therefore, while the identified regime shifts are statistically robust, the specific mechanisms – learning-by-exporting and the technology-

driven productivity premium from imports – should be interpreted as plausible explanations consistent with the data rather than causally established effects. Future research incorporating direct technological indicators could further validate these interpretations.

***Recommended managerial interventions for exports and imports.*** The identified threshold values of 7.5% for exports and 17.5% for imports define qualitatively distinct operational regimes requiring differentiated policy responses.

Export Policy: Targeting the 7.5% Threshold. Maximum marginal returns on labor costs ($\beta_1^{exp}$ = 833.72) occur precisely in the sub-threshold zone. The policy objective should therefore shift from maximizing aggregate export volumes toward assisting enterprises in crossing and consolidating within the 7.5% threshold zone – the zone of peak labor efficiency. Since export credit insurance is already available through the Export Credit Agency of Ukraine, the primary policy opportunity lies in:

- Targeting ECA instruments toward enterprises with export shares between 3–7%, where marginal returns on state support are highest. Enterprises already above 7.5% are in the diminishing returns zone and require innovation-oriented rather than volume-oriented support.
- Reorienting certification programs toward small enterprises (10–49 employees), whose productivity showed the greatest sensitivity to threshold crossing in the 2017–2024 data.
- Replacing one-off transaction support with instruments that build sustained export relationships, since Regime 1 efficiency gains require export activity to become a stable operational component.

Import Policy: Targeting the 17.5% Threshold. Import returns accelerate beyond 17.5% ($\beta_2$imp = 436.28 versus $\beta_1$imp = 349.32 – a 25% increase in marginal labor efficiency), while fragmented importing below this threshold generates net transaction costs that outweigh productivity gains, as confirmed by the negative trend in Regime 1 ($y = -16.2x + 1355.2$). Policy instruments should therefore:

- Provide targeted customs duty reductions for intermediate goods imports for enterprises with current import shares between 10–17%, explicitly calibrated to facilitate transition across the systemic threshold – distinct from general tariff liberalization.
- Integrate import support with workforce upskilling programs, since the 25% productivity gain in Regime 2 operates through enhanced labor efficiency and requires complementary human capital investment.

The Asymmetric Integration Model. The combined evidence supports a strategy in which enterprises maintain export shares within the high-marginality zone (up to 7.5%) while increasing import dependence beyond the systemic threshold (above 17.5%). This configuration activates technological drivers through imports, preserves maximum labor efficiency returns through exports, and minimizes vulnerability to external shocks by avoiding the diminishing returns zone on the export side.

Future research could productively examine the industry-specific nature of the identified thresholds, where the impact of international trade activity may exhibit different critical values.

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# ПОРОГОВІ ЕФЕКТИ ЗОВНІШНЬОЕКОНОМІЧНОЇ ДІЯЛЬНОСТІ ТА ПРОДУКТИВНІСТЬ ПРАЦІ: ЕМПІРИЧНЕ ДОСЛІДЖЕННЯ

**В с т у п .** ***Досліджено нелінійний вплив експортної та імпортної діяльності на продуктивність праці українських малих і середніх підприємств у період надзвичайної макроекономічної нестабільності (2017–2024 рр.), що охоплює пандемію COVID-19 та повномасштабну війну. Зазначено критичні точки структурного розриву, які відокремлюють початкову міжнародну діяльність від системних операцій в умовах воєнних потрясінь.***

**М е т о д и .** ***Використано методологію порогової регресії панельних даних для ендогенного виявлення структурних розривів. Модель враховує індивідуальні фіксовані ефекти для контролю за непомітною гетерогенністю на рівні підприємств. У дослідженні чітко розглядаються обмеження, пов'язані з невеликим розміром вибірки (30 спостережень), та вплив вимушеної рекласифікації розміру підприємств через масову міграцію робочої сили та мобілізацію під час повномасштабного вторгнення.***

**Р е з у л ь т а т и .** ***Емпіричний аналіз підтверджує, що взаємозв'язок між продуктивністю та витратами на персонал залежить від інтенсивності міжнародної діяльності. Для експортної моделі ($R^2$ = 0,539) визначено поріг у 7,5 %. Нижче цієї межі підприємства відчувають "початковий імпульс" із високою граничною віддачею ($\beta_1$ = 833,72). Понад цю позначку віддача зменшується ($\beta_2$ = 726,85), що свідчить про те, що подальше зростання вимагає глибокої технологічної інтеграції. У моделі імпорту ($R^2$ = 0,508) встановлено системний поріг у 17,5 %. У другому режимі виявлено "технологічний бонус", коли ефективність праці зростає на 25 % завдяки інтеграції іноземних високотехнологічних проміжних товарів у виробничі цикли.***

**В и с н о в к и .** ***Результати дослідження вказують на необхідність переорієнтації економічної політики на цільові заходи. Для підприємств, що не досягають 7,5 % експортного порогу, підтримка має зосередитися на зниженні бар'єрів для входу на ринок за допомогою експортно-кредитних агентств. Для тих, хто перевищує цей ліміт, політика має зосередитися на стимулюванні науково-дослідницької діяльності. Щодо імпорту, дослідження пропонує вибіркову лібералізацію митних бар'єрів для високотехнологічних ресурсів, що сприятиме подоланню бар'єру ефективності у 17,5 %. Ці рекомендації надають дорожню карту для підвищення економічної стійкості в умовах повномасштабної війни.***

**К л ю ч о в і  с л о в а :** ***продуктивність праці, порогова регресія, експорт, імпорт, поріг системності, імпортозалежність, воєнний стан.***

Федулова Ірина є членом редколегії видання, тому не брав участі у рецензуванні та прийнятті рішення щодо публікації цієї статті.

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