



# УКРАЇНСЬКА ЕКОНОМІКА ПІД ЧАС ВОЄННОЇ АГРЕСІЇ РФ І В ПЕРІОД ПІСЛЯВОЄННОГО ВІДНОВЛЕННЯ

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## UKRAINIAN ECONOMY DURING THE MILITARY AGGRESSION OF THE RUSSIAN FEDERATION AND IN THE POST-WAR RECOVERY PERIOD

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### ESTIMATING THE ECONOMIC COST OF WAR, UKRAINE (2014-2023): SYNTHETIC CONTROL METHOD

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*This article estimates the cumulative economic cost of the war for Ukraine from 2014 to 2023 using the Synthetic Control Method. The study identifies structural shifts in Ukraine's macroeconomic indicators resulting from Russia's military aggression. By constructing a counterfactual "synthetic Ukraine" from a weighted mix of peer economies, the analysis quantifies the cumulative GDP loss.*

**Keywords:** economic losses; GDP gap; robustness; Synthetic Control Model; war.

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The Russian military aggression against Ukraine since 2014 has inflicted severe economic and social damage, but its true macroeconomic cost is difficult to measure. Direct losses (labor force and fixed capital, including infrastructure) are widely reported, yet the cumulative output foregone as a result of war remains uncertain. This paper uses the Synthetic Control Method (SCM) to estimate Ukraine's output trajectory in the absence of war and to compute the lost nominal GDP PPP

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due to conflict. SCM is an experimental causal inference technique that constructs a weighted combination of similar units (in this case, other countries) to serve as a counterfactual for a treated unit. By comparing Ukraine's actual GDP per capita PPP<sup>1</sup> to that of a synthetic Ukraine, we infer the causal effect of war on GDP. Our SCM analysis reveals a large, growing GDP gap after 2014, implying substantial losses discussed in detail in the Findings section. Quantifying this gap provides an evidence-based benchmark for the scale of post-war reconstruction.

International financial institutions and academic researchers have extensively analyzed the economic cost of war in Ukraine. The initial Russian aggression in 2014 triggered a sharp economic contraction — GDP fell by 6.6% in 2014 and 9.8% in 2015<sup>2</sup>, driven by industrial disruptions in Donbas, severe inflation, and investor flight. Although Ukraine experienced partial recovery by 2021, the full-scale invasion in 2022 reversed those gains: GDP contracted by nearly one-third and poverty surged fivefold<sup>3</sup>. The study conducted by KSE includes infrastructure damage and lost output, placing war-related losses above \$1 trillion (Stepanov et al., 2024).

To quantify the macroeconomic cost of war beyond physical destruction, economists have increasingly employed the Synthetic Control Method. This method constructs a counterfactual, “synthetic” scenario — what would have happened in the absence of war — using weighted comparisons from unaffected countries. Core theoretical studies by A. Abadie & J. Gardeazabal (2003) and A. Abadie et al. (2015) demonstrated SCM's utility in measuring GDP impacts of terrorism in the Basque Country and economic outcomes following German reunification. In Ukraine's case, J. Bluszcz & M. Valente (2020) applied SCM to estimate that the hybrid warfare in the Donbas region led to an average decline in GDP per capita of 15.1% between 2013 and 2017, with even greater losses in regional output for Donetsk and Luhansk. More recently<sup>4</sup>, employed SCM to assess cumulative GDP losses over the full decade of war, finding that Ukraine's economy contracted by approximately \$1.57 trillion relative to a synthetic comparator.

Other studies have extended SCM to narrower economic domains: D. Audretsch et al. (2023) examined wartime impacts on entrepreneurship, identifying a 15–20% drop in self-employment and SME activity. Similarly, sectoral applications have explored disruption in industrial output, foreign trade, and infrastructure-

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<sup>1</sup> GDP per capita, PPP (current international \$) — Ukraine. World Bank Group. *World Bank Group*. URL: <https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD?end=2024&locations=UA&start=2013&view=chart> (accessed: 10.05.2025).

<sup>2</sup> The World Factbook — Ukraine (2022 Archive). *Central Intelligence Agency*. 2022. URL: <https://www.cia.gov/the-world-factbook/about/archives/2022/countries/ukraine/> (accessed: 18.05.2025).

<sup>3</sup> Ukraine rapid damage and needs assessment Released. *World Bank Group*. 2025. Feb 25. URL: <https://www.worldbank.org/en/news/press-release/2025/02/25/updated-ukraine-recovery-and-reconstruction-needs-assessment-released> (accessed: 10.05.2025).

<sup>4</sup> Williams C., Flower A., Prantyuk O. A commentary on potential reparations claims arising from the Russia–Ukraine conflict. *HKA*. 2024. May 15. URL: <https://www.hka.com/article/a-commentary-on-potential-reparations-claims-arising-from-russia-ukraine-conflict/> (accessed: 10.05.2025).



**Fig. 1.** Donor Pool of 18 Countries for the Synthetic Control Model of Ukraine  
*Source:* author's visualization using MapChart. URL: <https://www.mapchart.net/world.html> (accessed: 15.05.2025).

dependent sectors, confirming that the war's economic effects extend beyond GDP into productivity and employment dynamics. Several SCM studies also emphasize the temporal layering of conflict, with effects compounding over time and intensifying after the full-scale invasion of 2022. These works collectively demonstrate SCM's relevance not only for measuring losses but also for informing post-war policy, reparations discussions, and recovery frameworks grounded in empirical evidence (Chupilkin, Kóczán, 2022).

**The purpose of this article** is to empirically quantify the macroeconomic cost of the Russian aggression against Ukraine by applying the Synthetic Control Method to construct a credible counterfactual of Ukraine's economic trajectory in the absence of conflict, thereby estimating the cumulative GDP loss sustained between 2014 and 2023 and providing policymakers with a robust evidence-based benchmark to guide the scale and strategic priorities of post-war reconstruction.

**Methodology.** Using the World Bank data library, we compiled annual macroeconomic data for Ukraine and a set of 18 peer countries in Europe and Central Asia covering the period from 1996 to 2023 (Fig. 1); these donor countries, highlighted in red on the map, were selected based on shared post-socialist institutional legacies, comparable income levels, geographic proximity, the absence of large-scale internal or external conflicts during the study window, and the availability of the necessary data, thereby ensuring that the synthetic control unit is constructed from credible economic analogues reflecting the mix of low-value-added industrial, agricultural, and service-based activities typical of Ukraine's economy before 2014, while countries in yellow, including Russia and Belarus, were excluded due to their direct involvement in the conflict, and Ukraine itself is shown in blue.

According to A. Abadie & J. Gardeazabal (2003), the **Synthetic Control Method** constructs an artificial version of Ukraine by assigning each donor a non-

negative weight so that the weighted average best reproduces Ukraine's actual macroeconomic trajectory in the pre-treatment period.

Formally, the synthetic GDP per capita PPP at time  $t$  is defined as

$$\tilde{Y}_t = w_1 Y_{1,t} + w_2 Y_{2,t} + \dots + w_j Y_{j,t} + \dots + w_N Y_{N,t} = \sum_{j=1}^N w_j Y_{j,t},$$

where  $\tilde{Y}$  is the value of the synthetic control GDP for Ukraine in year  $t$ ;  $Y_{j,t}$  is the fact GDP of donor country  $j$  in year  $t$ ;  $w_j$  is the weight for donor country  $j$ , and  $N$  is the total number of donor countries.

The weights are constrained to sum to 1 and remain non-negative:

$$w_j \geq 0, \quad \text{and} \quad \sum_{j=1}^N w_j = 1.$$

The primary outcome variable is GDP per capita, PPP (current international dollars), which is the standard measure for comparing living standards across countries. The vector of donor weights is determined by solving an optimization problem that minimizes the weighted squared distance between Ukraine's observed predictors and the corresponding predictors of the donor pool. The full list of predictors used for this study: Agriculture, forestry, and fishing, value added (% of GDP); Current account balance (% of GDP); Domestic credit to private sector (% of GDP); Exports of goods and services (% of GDP); Exports of goods and services (current US\$); Foreign direct investment, net inflows (% of GDP); Foreign direct investment, net inflows (current US\$); GDP per capita, PPP (current international \$); GNI, PPP (current international \$); Imports of goods and services (% of GDP); Industry (including construction), value added (annual % growth); Population, total; PPP conversion factor (GDP) to market exchange rate; Services, value added (% of GDP).

The pre-treatment period, from 1996 to 2013, provides sufficient length to capture multiple economic cycles and ensures that the synthetic control faithfully mirrors Ukraine's growth path under stable conditions.

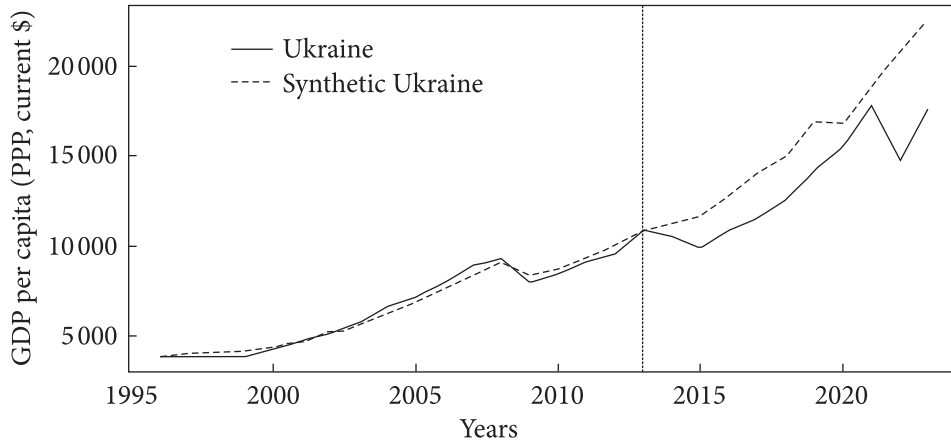
$$\min_W (X_1 - X_0 W)_t V(X_1 - X_0 W)_t,$$

where  $W$  is a vector of weights applied to the control units, and  $X_1 \in R^k$  be a vector of pre-treatment averages of predictor variables for Ukraine (such as GNI per capita, FDI inflows, sectoral shares, trade openness, etc.), and  $X_0 \in R^{kj}$  be the corresponding matrix for the donor countries.

After fitting the synthetic control for the period 1996-2013, we assess its credibility by examining the pre-treatment Root Mean Square Error (RMSE). A low RMSE indicates a precise match. For this study, the pre-2014 RMSE was approximately 282 (which accounts for ~2% of 2013 GDP per capita PPP), demonstrating that synthetic Ukraine closely approximates the actual economic path in the absence of war.

Once the conflict began in 2014 (marked by the annexation of Crimea and the outbreak of hostilities in the Donbas), the difference between the observed and synthetic GDP per capita is interpreted as the causal effect of the war on Ukraine's economic performance. This gap at time  $t$  is defined as

$$\Delta_t = Y_{UA,t} - \tilde{Y}_t.$$



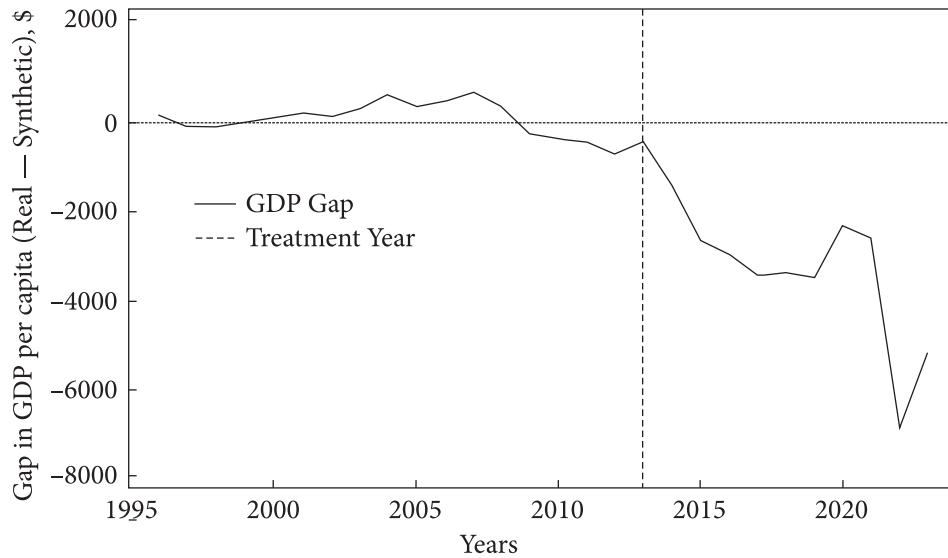
**Fig. 2.** SCM trend plot (actual vs. synthetic GDP per capita, PPP, 1996-2023)  
 Source: author's calculation using SCM in R based on: *World Bank*. 2023. URL: <https://data.worldbank.org/> (accessed: 05.05.2025).

The data processing, model estimation, and robustness checks were performed in *R*, using SCM packages, and validated through placebo and leave-one-out tests. This ensures that the estimated GDP per capita gap is robust, transparent, and derived exclusively from empirical data reflecting Ukraine's macroeconomic history and its regional peers. The final stage of the analysis translates the per-capita shortfall into aggregate monetary terms, providing a concrete benchmark for policymakers. All data used to construct the SCM are taken from the World Bank dataset<sup>5</sup>.

**Findings.** Fig. 2 shows the actual and synthetic GDP per capita PPP of Ukraine over the entire study period, 1996-2023. In the calibration period 1996-2013, before the war, based on which the country weights for the SCM were determined, the two lines move very close to each other, with the dashed line representing the synthetic Ukraine (estimating the counterfactual no-war scenario) and the solid line indicating the actual observed GDP per capita. The root mean square error (RMSE) is approximately 282, which supports that the synthetic mirrors the actual one, as the GDP per capita PPP was \$3,812.25 in 1996 and grew to \$10,903.83 in 2013. However, from 2014, the actual GDP per capita curve departs sharply below the synthetic projection. This marked deviation, persisting over time and deepening post-2022 with the full-scale invasion, underscores the compounded economic toll of prolonged conflict. The RMSE in the 2014-2023 war period is 3,036, 10.76 times its pre-war divergence.

The donor composition underlying the synthetic control sheds further light on the credibility of the counterfactual estimate. In this setting, the synthetic Ukraine is constructed primarily from three key donor countries: Armenia, which carries a weight of 0.54, Romania, with a weight of 0.35, and Hungary, contributing a weight of 0.10, while all other countries from the donor pool stand for less than 0.01 but serve as an important calibrator. The prominence of Armenia suggests that its post-

<sup>5</sup> World Development Indicators. World Bank. 2025. *World Bank Group*. URL: <https://data.worldbank.org/> (accessed: 18.05.2025).



**Fig. 3.** SCM gap plot (actual minus synthetic GDP per capita, PPP, 1996-2023)  
 Source: author's calculation using R based on: *World Bank*. 2023. URL: <https://data.worldbank.org/> (accessed: 05.05.2025).

Soviet development path, without a North Atlantic integration process, most closely mirrored Ukraine's pre-2014 macroeconomic dynamics among the available peers. Meanwhile, Romania and Hungary, two other post-socialist countries, supplement the synthetic construct by providing structural and institutional characteristics as well as North Atlantic integration typical of more advanced transition economies.

The widening gap after 2014 is more explicitly demonstrated in the GDP gap plot (Fig. 3), which visualizes the difference between actual and synthetic GDP per capita for each year after the onset of war. The solid curve depicts the annual difference, with negative values indicating that Ukraine's actual economic performance has lagged behind its estimated no-war trajectory, while the vertical dashed line marks the intervention point in 2014. By 2021, Ukraine's GDP per capita stood approximately 1,006.6 US dollars (PPP) below what the synthetic control predicts it would have been in the absence of war. A notable initial drop in 2014-2015 and a further sharp decline post-2022 highlight the sustained cost of the conflict.

The 2021 shortfall translates to about six percent lower GDP per capita than the counterfactual level. When scaled up using the World Bank estimated population of 44.3 million people (2021), the national output loss attributable to this gap amounts to roughly 44.6 billion US dollars in PPP terms, equivalent to approximately 325.6 billion Ukrainian UAH in nominal terms for the same year alone. Extending this calculation by using annual gaps of the post-2014 period presented in Table 1, the cumulative loss in GDP (in constant PPP dollars) reaches an estimated 1.1 trillion US dollars over the decade, capturing both the immediate contraction and the long-term suppression of economic growth that the conflict has imposed on Ukraine's economy.

It is appropriate to compare the estimated cumulative GDP shortfall of 1.1 trillion US dollars with the figure referenced in the literature review, namely

the 1.57 trillion US dollars reported by C. Williams, A. Flower, and O. Prantnyuk (2024), which was also calculated using the Synthetic Control Method. While the difference between the two estimates is substantial, it is not unexpected given that methodological differences — such as the specification of the donor pool, the selection of predictors, and most importantly, the time horizon of the study. Nevertheless, both estimates clearly highlight the staggering long-term economic impact of the conflict on Ukraine, reinforcing that the Russian aggression has driven a persistent divergence from its potential growth path, which will be difficult to close without sustained reconstruction and comprehensive policy support.

**Robustness.** Beyond the facts that the donor country weights are in line with common sense expectations, and the RMSE between Ukraine’s facts and the synthetic control figures jumps up by a factor of more than 10 right after the beginning of the war in 2014, we still need to run a few robustness checks.

**Placebo Test.** To confirm that the estimated GDP gap is not merely the result of statistical noise or an artifact of model construction, the analysis includes a comprehensive placebo test strategy, following standard practice in synthetic control applications. The core idea behind a placebo test is to apply the same SCM estimation procedure to a country that did not experience the intervention — in this case, the outbreak of a war — to check whether a similar divergence could appear purely by chance. If the model falsely detects a significant gap in an unaffected country, this would cast doubt on the validity of the causal inference for Ukraine. Conversely, if the placebo countries show no structural break, it strengthens the conclusion that Ukraine’s gap is a genuine effect of the conflict.

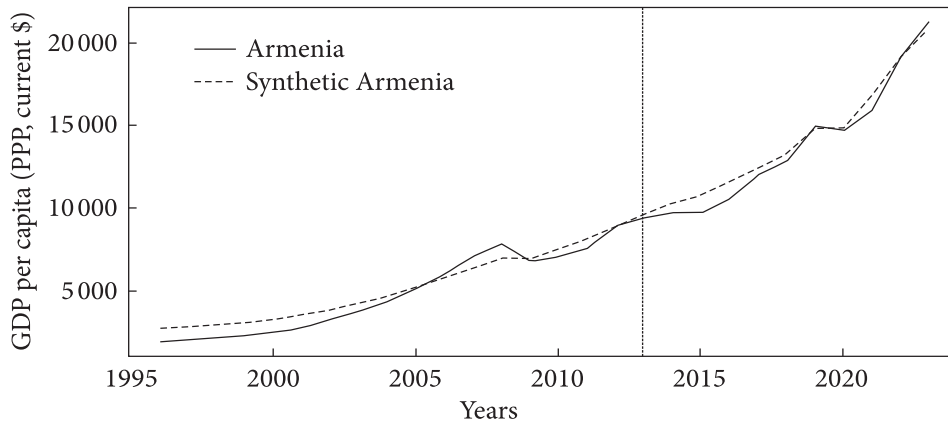
In this study, Armenia was selected as a primary placebo test case because it serves as the largest-weighted donor in the construction of synthetic Ukraine. By treating Armenia as if it had hypothetically experienced a comparable conflict beginning in 2014, the model re-estimates a synthetic control for Armenia using the same donor pool, predictors, and pre-treatment window. Applying the 2014 “treatment” to Armenia (which did not experience war) yields no structural break: the actual (black) and synthetic (dashed) lines remain parallel after 2014.

The resulting comparison depicted in Fig. 4 demonstrates that Armenia’s actual GDP per capita remains closely aligned with its synthetic counterpart throughout the

*Table 1. Ukraine vs. Synthetic GDP and Gap (1996-2023)*

|              |        |        |        |        |        |
|--------------|--------|--------|--------|--------|--------|
| Indicator    | 2014   | 2015   | 2016   | 2017   | 2018   |
| GDP Gap (\$) | -775   | -1,735 | -1,921 | -2,550 | -2,404 |
| Indicator    | 2019   | 2020   | 2021   | 2022   | 2023   |
| GDP Gap (\$) | -2,707 | -1,291 | -1,007 | -6,139 | -4,992 |

*Source:* author’s calculation using SCM in R based on: *World Bank Group*. 2023. URL: <https://data.worldbank.org/> (accessed: 10.05.2025).



**Fig. 4.** Placebo SCM plot for Armenia (actual vs. synthetic GDP per capita, PPP, 1996-2023)  
 Source: author’s calculation using SCM in R based on: *World Bank Group*. 2023. URL: <https://data.worldbank.org/> (accessed: 09.05.2025).

**Table 2. Pre- and post-2014 RMSE (in current US \$) of the synthetic control in selected countries**

| Country | Pre-2014 | Post-2014 | Ratio | Country | Pre-2014 | Post-2014 | Ratio |
|---------|----------|-----------|-------|---------|----------|-----------|-------|
| Ukraine | 282      | 3036      | 10.6  | Romania | 1000     | 1300      | 1.3   |
| Armenia | 577      | 630       | 1.1   | Hungary | 690      | 1091      | 1.6   |

Source: author’s calculation using SCM in R based on: *World Bank Group*. 2023. URL: <https://data.worldbank.org/> (accessed: 15.05.2025).

post-2013 period. While minor short-term fluctuations appear — as would be expected due to normal macroeconomic variability — there is no sustained or widening gap equivalent to what is observed for Ukraine. For Armenia’s placebo SCM, the pre-treatment RMSE of 577 only increases in the post-treatment period to 630, an insignificant difference that confirms the model does not systematically produce false positives when applied to a country unaffected by conflict.

Furthermore, additional placebo tests were conducted for other major donors such as Hungary and Romania. These countries similarly display no meaningful divergence between actual and synthetic GDP per capita after the pseudo-intervention date of 2014. In each case, the synthetic control continues to track the real economic trajectory with only minimal deviation, consistent with random macroeconomic fluctuations rather than structural economic shocks (Table 2). Collectively, these in-sample placebo checks demonstrate that the SCM, as applied in this study, is stable and conservative: it does not falsely attribute treatment effects where none exist.

The stark contrast between Ukraine’s pronounced and persistent GDP gap and the relatively minor deviations observed in placebo countries provides strong empirical evidence that the shortfall in Ukraine’s GDP per capita is a direct consequence of the war, rather than an artifact of the synthetic control methodology or data irregularities.

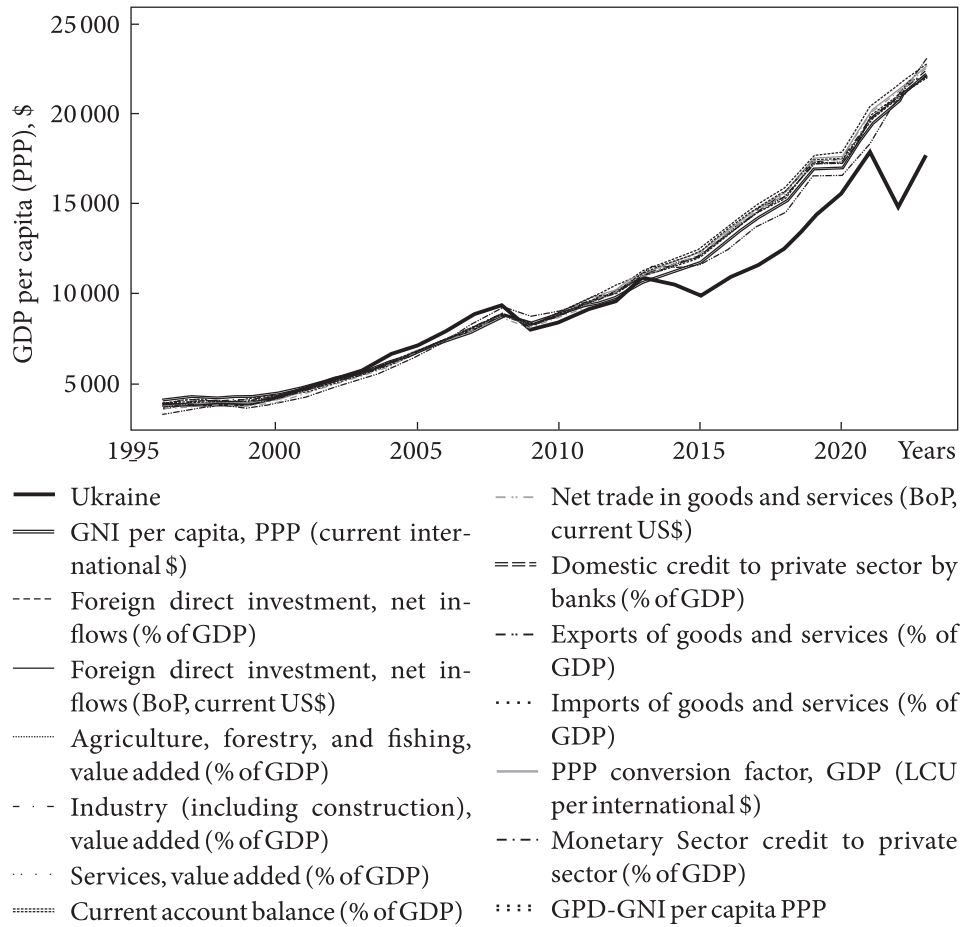
In Ukraine, the average GDP per capita (PPP) over the study period — calculated for the pre-2014 (\$6,731) and the post-2014 (\$13,538) values. The post-2014 RMSE of the synthetic control model is \$3,036, which amounts to a striking 22.4% of post post-treatment average, indicating a substantial divergence between actual and synthetic GDP paths. By contrast, Romania’s average GDP per capita PPP was \$11,247 for pre-2014 and \$31,626 post-2014, and its post-2014 RMSE of \$1,300 represents only 4.1% of the average. Hungary, with the averages of \$16,689 for pre-2014 and \$33,889 for post, shows a post-treatment RMSE of \$1,091 — just 3.2% of the mean. Lastly, Armenia’s gap: with the averages of \$5,088 and \$14,111 and an RMSE of \$630, the deviation is 4.4%. These comparative figures for post treatment — for Ukraine (22.4%) versus Romania (4.1%), Hungary (3.2%), and Armenia (4.4%) respectively — demonstrate that the deviation in Ukraine is not only the largest in absolute terms, but also disproportionately large relative to its economic size, reinforcing the conclusion that the war introduced a uniquely severe economic disruption not observed in unaffected countries.

**Leave-One-Out Test for Donor Pool.** To further test the robustness of the results, a leave-one-out (jackknife) procedure was applied, systematically exclu-

**Table 3. Pre- and post-2014 RMSE (in current US \$) values when one donor country is left out**

| Without a country | Pre-treatment RMSE | Post-treatment RMSE | Ratio |
|-------------------|--------------------|---------------------|-------|
| Poland            | 389.86             | 3238.55             | 8.31  |
| Romania           | 382.35             | 3704.65             | 9.67  |
| Bulgaria          | 339.57             | 3564.41             | 10.50 |
| Latvia            | 390.41             | 3232.68             | 8.28  |
| Lithuania         | 342.05             | 3509.38             | 10.26 |
| Estonia           | 338.84             | 3571.78             | 10.54 |
| Turkey            | 440.58             | 3661.34             | 8.31  |
| Croatia           | 347.10             | 3239.95             | 9.33  |
| Bosnia and H.     | 339.01             | 3579.15             | 10.56 |
| Moldova           | 600.78             | 3687.62             | 5.98  |
| Georgia           | 352.77             | 3342.48             | 9.47  |
| Armenia           | 347.94             | 3241.63             | 9.32  |
| Albania           | 356.34             | 3316.77             | 9.31  |
| Czechia           | 348.17             | 3246.20             | 9.32  |
| Serbia            | 339.73             | 3564.19             | 10.49 |
| Slovenia          | 391.06             | 3584.00             | 9.16  |
| Hungary           | 348.25             | 3231.09             | 9.28  |
| North Macedonia   | 348.71             | 3205.12             | 9.19  |

Source: author’s calculation using SCM in R based on: *World Bank Group*. 2023. URL: <https://data.worldbank.org/> (accessed:15.05.2025).



**Fig. 5.** Sensitivity analysis for Ukraine (actual vs. synthetic GDP per capita, PPP, 1996-2023)  
 Source: author's calculation using SCM in R based on: *World Bank*. 2023. URL: <https://data.worldbank.org/> (accessed: 15.05.2025).

ding each donor from the synthetic control model. In every case, the estimated treatment effect — the post-2013 GDP per capita gap — remained present and directionally consistent. The pre-treatment fit RMSE increased from the baseline value of 282 to a minimum of 338 (Estonia excluded), a median of 348.48, and a maximum of 600 when Moldova was excluded from the donor pool. Notably, excluding Hungary raised the RMSE to 348, Albania to 356, and Romania to 382. Table 3 illustrates these results in detail.

These increases demonstrate that no single donor drives the significant divergence. The synthetic Ukraine consistently overestimates actual GDP per capita after 2013, regardless of the donor configuration.

**Leave-One-Out Test for Predictors.** To evaluate the robustness of the Synthetic Control Model to predictor composition, a leave-one-out sensitivity analysis was conducted. Each of the 14 core economic indicators was systematically excluded from the model, one at a time, and a new synthetic Ukraine was generated.

**Table 4. Pre- and post-2014 RMSE values when one predictor variable is left out**

| Variable                                                   | Pre-2014 | Post-2014 | Ratio |
|------------------------------------------------------------|----------|-----------|-------|
| Original Model                                             | 282      | 3036      | 10.75 |
| GNI per capita, PPP (current international \$)             | 418.25   | 3033.59   | 7.25  |
| Foreign direct investment, net inflows (% of GDP)          | 389.4    | 3478.34   | 8.93  |
| Foreign direct investment, net inflows (BoP, current US\$) | 389.9    | 3240.37   | 8.31  |
| Agriculture, forestry, and fishing, value added (% of GDP) | 382.71   | 3704.54   | 9.68  |
| Industry (including construction), value added (% of GDP)  | 358.98   | 3216.08   | 8.96  |
| Services, value added (% of GDP)                           | 356.26   | 3141.17   | 8.82  |
| Current account balance (% of GDP)                         | 344.07   | 3481.36   | 10.12 |
| Net trade in goods and services (BoP, current US\$)        | 359.43   | 3243.25   | 9.02  |
| Domestic credit to the private sector by banks (% of GDP)  | 339.55   | 3279.75   | 9.66  |
| Exports of goods and services (% of GDP)                   | 518.14   | 3000.14   | 5.8   |
| Imports of goods and services (% of GDP)                   | 348.07   | 3227.16   | 9.27  |
| PPP conversion factor, GDP (LCU per international \$)      | 340.05   | 3556.71   | 10.46 |
| Monetary Sector credit to private sector (% of GDP)        | 347.74   | 3245.44   | 9.33  |
| GDP-GNI per capita PPP                                     | 381.58   | 3725.31   | 9.76  |

Source: author's calculation using SCM in R based on: World Bank Group. 2023. URL: <https://data.worldbank.org/> (accessed: 15.05.2025).

**Table 5. Ukraine's Foreign Trade (2013 vs 2019)**

| Region       | 2013          |           |               |           | 2019          |           |               |           |
|--------------|---------------|-----------|---------------|-----------|---------------|-----------|---------------|-----------|
|              | export, \$ mn | export, % | import, \$ mn | import, % | export, \$ mn | export, % | import, \$ mn | import, % |
| EU           | 16,758        | 26.5      | 27,046        | 35.1      | 20,751        | 41.5      | 25,012        | 41.1      |
| Russia       | 15,065        | 23.8      | 23,234        | 30.2      | 3,243         | 6.5       | 6,985         | 11.5      |
| Other CIS    | 6,998         | 11.1      | 4,697         | 6.1       | 3,511         | 7.0       | 4,892         | 8.0       |
| Other Europe | 467           | 0.7       | 1,582         | 2.1       | 512           | 1.0       | 2,180         | 3.6       |
| T o t a l    | 63,312        | 100.0     | 76,964        | 100.0     | 50,055        | 100.0     | 60,800        | 100.0     |

Source: compiled by the authors based on: State Statistics Service of Ukraine. 2019. URL: [ukrstat.gov.ua](http://ukrstat.gov.ua) (accessed: 10.05.25).

Across all specifications, the resulting synthetic counterfactuals remained directionally consistent with the baseline, continuing to diverge from actual Ukraine GDP per capita after 2013 (Table 4).

Gap curve analysis, visualized in Fig. 5, further confirms these insights. The plot examines the robustness of the synthetic control estimates by sequentially excluding each economic indicator from the donor pool. The actual GDP per capita (black line) diverges from all synthetic estimates (dashed lines) following the 2014 intervention (vertical dashed line), indicating a structural break. Importantly, none of the exclusions eliminated the treatment effect, and the close clustering of the synthetic lines suggests the results are not driven by any single indicator, reaffirming the model's robustness to changes in predictor structure. These findings suggest that the baseline results are not driven by any single variable, but rather reflect a stable and reliable synthetic construction.

While the overall shape of the post-treatment GDP gap for Ukraine persisted, the magnitude varied depending on which indicator was excluded from the synthetic control model. Notably, removing "GDP-GNI per capita PPP" produced the largest deviation from the baseline synthetic Ukraine, underscoring the importance of transferred private income from abroad in the context of the shock. In contrast, excluding "Exports of goods and services (% of GDP)" had the least impact.

This relative insensitivity might initially seem surprising, given that exports were one of the key economic concerns following the Russian invasion of Donbas in 2014, which led to a Russian embargo on Ukrainian goods. However, trade data reveal a rapid reorientation of Ukraine's export structure during this period (Table 5). In 2013, Russia accounted for 23.8% of Ukrainian exports, nearly matching the EU's 26.5%. By 2019, exports to Russia had dropped sharply to just 6.5%, while the EU's share surged to 41.5%, more than doubling Russia's. This pivot towards European markets likely mitigated the macroeconomic fallout from the trade disruption with Russia, explaining why exports as a share of GDP exerted relatively little influence on the synthetic control's post-treatment trajectory.

Overall, the persistence of the treatment effect across all specifications supports a robust, causal interpretation of Ukraine's observed GDP PPP gap.

Robustness checks strongly support these results. Placebo tests applied to donor countries unaffected by military conflicts show no comparable divergence after 2013, and leave-one-out analyses confirm that no single donor country or predictor variable drives the effect. The persistent and large post-treatment gap for Ukraine appears to be unique, demonstrating that the observed losses are a genuine consequence of sustained conflict and not a statistical artefact. Subsequently, the findings clearly quantify the substantial macroeconomic cost of the war for Ukraine and provide a credible, evidence-based benchmark for assessing the scale of recovery needed to restore lost economic potential.

## **DIRECTIONS FOR FURTHER RESEARCH**

We have to take into account that throughout a decade, not only war caused a deviation from the synthetic control path. Historically, the late 2013 — early 2014 Euro-Maidan revolution broke out because then-Ukrainian president Yanukovich refused to sign the association agreement with the EU. Regardless of other sequences, the revolution had two major economic consequences: the signing of the association

agreement with the EU and Russian military aggression. Hence, strictly speaking, the counterfactual benchmark for assessing the effect of the war should be a universe in which Ukraine has the association agreement, but there is no war. Such a reference path would certainly be higher in terms of per capita GDP than just the continuation of the previous SCM based on Armenia, which never signed an agreement, and Hungary-Romania, which had signed their agreements in the 1990s. However, it is difficult to estimate what such a purist baseline would have looked like because over the period 2014-2021, a number of important institutional changes and policy measures were introduced as a direct consequence of the association agreement.

**The Deep and Comprehensive Free Trade Area** implemented in 2016 had a significant influence on Ukraine's post-2014 economic recovery. This landmark agreement anchored Ukraine's strategic pivot toward the European single market, helping to compensate for the loss of traditional trade with Russia. The AA/DCFTA nearly eliminated tariffs on goods trade (over 98% of tariff lines liberalized on both sides<sup>6</sup>, facilitating a surge in exports and deepening economic linkages with the EU.

Between 2013 and 2021, Ukraine's trade with the EU grew by 48%, even as total trade with Russia fell by 78%. The EU's share of Ukraine's exports rose from 24.9% in 2012 to 37.1% by 2016, and reached approximately 41% in 2021, making the EU Ukraine's largest trading partner. In fact, by 2019, Ukraine's goods exports to the EU were 24% higher in USD terms than in pre-crisis 2013, reflecting gains particularly in the agriculture/food, machinery, and metals sectors<sup>7</sup>. On the eve of the 2022 invasion, the CIS countries accounted for just 15% of Ukraine's trade turnover, while the EU comprised roughly 40%, marking a decisive structural reorientation westward<sup>8</sup>.

Beyond trade volume, DCFTA induced significant transformations in product standards, customs procedures, and regulatory alignment. Ukrainian exporters increasingly complied with EU sanitary and phytosanitary rules, enabling the country to increase its trade by 130 percent from 2014 to 2021 in the European market<sup>9</sup>. Simultaneously, the EU supported Ukraine with institutional and technical assistance: over €17 billion in grants and macro-financial aid between 2014 and 2021 funded reforms in governance, energy efficiency, infrastructure, and SME development.

<sup>6</sup> Association Implementation Report on Ukraine. Brussels, European Commission, 2022. 20 p. URL: <https://www.eeas.europa.eu/sites/default/files/documents/Association%20Implementation%20Report%20on%20Ukraine%20-%20Joint%20staff%20working%20document.pdf>

<sup>7</sup> How to Liberalise EU-Ukraine Trade under DCFTA: Tariff Rate Quotas. *Free Network*. 2020. Jun 04. URL: <https://freepolicybriefs.org/2020/06/04/how-to-liberalise-eu-ukraine-trade-under-dcfta-tariff-rate-quotas/> (accessed: 18.04.2025).

<sup>8</sup> Values-based partnership: Why the EU needs to accelerate trade with Ukraine. *Politico*. 2025. Apr 08. URL: <https://www.politico.eu/sponsored-content/values-based-partnership-why-the-eu-needs-to-accelerate-trade-with-ukraine/> (accessed: 15.05.2025).

<sup>9</sup> Analysis. Trade Effects of the EU-Ukraine Deep and Comprehensive Free Trade Agreement. National Board of Trade Sweden, 2024. URL: <https://www.kommerskollegium.se/globalassets/publikationer/rapporter/2024/trade-effects-of-the-eu-ukraine-deep-and-comprehensive-free-trade-agreement.pdf>

These developments collectively supported macroeconomic stabilization, current account correction, and export diversification. By 2021, the agricultural sector — one of the biggest DCFTA beneficiaries accounted for over 40% of Ukraine's merchandise exports, up from 27% in 2013<sup>10</sup>. Moreover, a large share of this growth came from higher-value processed goods, indicating an upward shift in Ukraine's exports.

The deepening of EU market access not only drove an export-led recovery in the latter half of the 2010s but also anchored Ukraine to a legal and economic framework of modernization. The Association Agreement created legally binding benchmarks for reforms in public procurement, competition policy, customs modernization, and environmental standards, pushing Ukraine toward European norms. These reforms contributed to improved rankings in international indices: for example, Ukraine's Doing Business score rose from 52.3 in 2014 to 70.2 in 2020<sup>11</sup>. Overall, the Association Agreement's integrationist influence provided a vital external engine for growth, modernization, and economic resilience during the recovery period. It substituted lost Russian markets with European alternatives, mobilized institutional support for structural reforms, and raised investor confidence in Ukraine's long-term orientation. This progress underscores that closer economic integration with the EU has been — and will continue to be — a pillar of Ukraine's resilience.

Equally critical, Ukraine undertook sweeping domestic reforms after 2014 in response to the crisis, which strengthened its economic fundamentals and capacity for recovery.

**Macroeconomic stabilization and fiscal adjustment.** The shock of 2014-2015 was severe: GDP contracted by 17% from the 2013 peak to the 2015 trough, inflation hit 43% in 2015<sup>12</sup>, and the hryvnia lost two-thirds of its value, sliding from ~8 UAH/USD in early 2014 to 25-27 UAH/USD in early 2015 (Ash, 2018). However, decisive policy reforms reversed the slide. By 2016, the economy returned to growth (+2.3% real GDP), while inflation cooled to around 15%, and currency fluctuations stabilized<sup>13</sup>. The overall budget deficit was reduced from ~10% of GDP in 2014 to 2.3% by 2016, and a modest surplus emerged by mid-2017<sup>14</sup>.

**Banking-sector cleansing and financial stabilization.** Under the guidance of the National Bank, over 90 banks (out of ~180) were liquidated or restructured

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<sup>10</sup> External trade of Goods, 2012-2021. *State Statistics Service of Ukraine*. 2022. URL: <https://stat.gov.ua/en/datasets/external-trade-goods> (accessed: 10.05.2025).

<sup>11</sup> Doing Business 2020: Comparing business regulation in 190 economies. *World Bank Group*. URL: <https://openknowledge.worldbank.org/entities/publication/130bd2f3-f4b5-5b77-8680-01e6d6a87222> (accessed: 05.05.2025).

<sup>12</sup> Inflation Report July 2016. Kyiv, NBU. 57 p. URL: [https://bank.gov.ua/admin\\_uploads/article/IR\\_2016-Q3\\_eng.pdf](https://bank.gov.ua/admin_uploads/article/IR_2016-Q3_eng.pdf)

<sup>13</sup> Annual Report 2018. National Bank of Ukraine, 2018. URL: [https://bank.gov.ua/admin\\_uploads/article/annual\\_report\\_en\\_2018.pdf](https://bank.gov.ua/admin_uploads/article/annual_report_en_2018.pdf)

<sup>14</sup> Ukraine: 2016 Article IV Consultation and third review under the Extended Arrangement (IMF Country Report No. 17/83). *International Monetary Fund*. 2017. URL: <https://www.elibrary.imf.org/view/journals/002/2017/083/article-A000-en.xml> (accessed: 14.05.2025).

between 2014 and 2017 in a crackdown on fraudulent practices, reducing public risk exposure. Most significantly, PrivatBank, the country's largest lender, was nationalized in December 2016 following the revelation of a \$5.5 billion capital deficit due to insider lending<sup>15</sup>. These reforms, backed by international donors (IMF, EBRD, WB), restored financial confidence and removed fiscal liabilities.

**Monetary reform and inflation targeting.** Following the 2014 drop of the hryvnia, the NBU implemented major reforms to mandate independence and introduced inflation targeting in 2016. It raised policy interest rates to ~30% in early 2015 to rein in inflation, which fell from 43% in 2015 to ~15% in 2016, stabilizing around 5-7% by 2018-2019<sup>16</sup>. These actions not only restored monetary credibility but also helped recover foreign exchange reserves and the basis for financial stability.

**Anti-corruption and governance.** One of the most visible achievements was ProZorro, a national e-procurement platform launched in August 2016. In its first two years, ProZorro generated an estimated \$1.9 billion in direct savings, representing nearly 2% of annual GDP<sup>17</sup>. This success in enhancing transparency and efficiency in public spending set a powerful model for future governance mechanisms.

**Impact and cumulative outcomes.** By eliminating energy subsidies, cleaning up banks, taming inflation, and reducing fiscal deficits, Ukraine reversed its 2014-2015 crisis and reestablished macroeconomic balance. Its fiscal integrity was restored within two years, the banking system stabilized by 2017, and government spending became more transparent. The recovery also laid the groundwork for post-2022 reconstruction initiatives — the improved policy landscape ensures foreign aid, private investment, and reconstruction spending produce meaningful economic returns and contribute directly to closing the GDP shortfall identified by SCM.

## CLOSING THE GAP

The SCM-based estimates of Ukraine's lost GDP carry significant implications for policymakers designing both immediate recovery measures and long-term development strategies. First and foremost, the magnitude of the identified output gap underscores the scale of investment required to bring Ukraine's economy back to its pre-war growth trajectory. For 2021 alone (the narrowest point of the gap), closing an annual shortfall of approximately ₴325.6 billion in nominal GDP would demand substantial capital inflows, fiscal support, and coordinated external assistance. When considered cumulatively, the estimated loss of nearly \$1.1 trillion PPP over the 2014-2023 period establishes a concrete benchmark for the total economic damage that post-war recovery must address, even if the war happens to end now.

<sup>15</sup> Comments on June 2016 Inflation Figures. *National Bank of Ukraine*. 2016. Jul 11. URL: <https://bank.gov.ua/en/news/all/komentar-natsionalnogo-banku-schodo-rivnyainflyatsiyi-v-chervni-2016-roku> (accessed: 03.05.2025).

<sup>16</sup> Inflation Report: April 2019. *National Bank of Ukraine*. 2019. National Bank of Ukraine. 64 p. URL: [https://bank.gov.ua/admin\\_uploads/article/IR\\_2019-Q2\\_en.pdf](https://bank.gov.ua/admin_uploads/article/IR_2019-Q2_en.pdf)

<sup>17</sup> eProcurement system ProZorro. *Observatory of Public Sector Innovation*. 2018. URL: <https://oecd-opsi.org/innovations/eprocurement-system-prozorro/> (accessed: 01.05.2025).

Additionally, the composition of the synthetic control provides useful reference cases. Armenia's trajectory, with the highest donor weight, demonstrates how a lower-middle-income post-Soviet country can sustain steady growth despite unstable conditions. Romania's and Hungary's experiences further illustrate how structural reforms, EU integration, and investment in competitiveness can propel transition economies toward higher income brackets. While Ukraine's situation — especially after the full-scale 2022 invasion — is unique in its scale of destruction and external security threats, these comparator paths offer practical insights into feasible reform sequencing and investment prioritization in a transitional, post-war context.

Finally, the robustness of the SCM estimates — validated with leave-one-out and placebo tests — means the €325.6 billion annual output gap and cumulative \$1.1 trillion PPP shortfall can be confidently used as targets for recovery planning. By combining these reform-driven gains with an export-driven recovery under the AA/DCFTA, Ukraine is well-positioned to fully leverage domestic and international investments to eliminate the war-induced loss and restore sustainable growth.

## CONCLUSION

This study applies the Synthetic Control Method to provide a rigorous, empirical estimate of the real economic cost of the Russian aggression for Ukraine between 2014 and 2023. By constructing a credible counterfactual using a donor pool of 18 comparable regional economies, the analysis shows that Ukraine's actual GDP per capita diverged sharply from its no-conflict trajectory beginning in 2014 and widened significantly following the full-scale invasion in 2022. The model fits Ukraine's pre-war economic trend with high precision, as evidenced by a low pre-treatment RMSE of 282. This sharply increases to over 3,000 in the post-treatment period — equivalent to 30% of Ukraine's average GDP per capita over the study period — confirming the presence of a substantial and sustained structural break. This level of deviation is not observed in placebo countries, reinforcing the conclusion that the war — not model error or data anomalies — is the primary driver of Ukraine's economic divergence.

By 2021, the per-capita GDP shortfall dropped to approximately \$1,007 in PPP terms, equivalent to about six percent below the estimated counterfactual level. Scaled to the national population, this implies a one-year GDP loss of roughly \$44.6 billion (or about €325.6 billion in nominal terms), while the cumulative loss across the entire decade is estimated at nearly \$1.1 trillion PPP. Robustness checks, including placebo tests for unaffected donor countries and systematic leave-one-out analyses, confirm that this gap is not a spurious artifact but a genuine consequence of sustained conflict.

Beyond quantifying economic losses, the results hold direct implications for economic recovery and policy design. The clear measurement of the war-induced output gap provides a practical benchmark for calibrating fiscal needs, external aid, and investment priorities. Integrating the SCM estimates in recovery modeling enables policymakers to set a target for the resource allocation efficiently, ensuring that

reconstruction spending translates into maximizing the output gains. Moreover, the donor countries with the highest weights in the synthetic control — Armenia, Romania, and Hungary — offer relevant transition experiences that can inform reform sequencing and institutional rebuilding in Ukraine's unique context. In sum, the SCM-based analysis not only clarifies the scale of Ukraine's economic damage but also translates abstract macroeconomic losses into actionable recovery goals.

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#### ОЦІНКА ЕКОНОМІЧНИХ ВТРАТ ВІД ВІЙНИ (УКРАЇНА У 2014—2023 рр.): МЕТОД СИНТЕТИЧНОГО КОНТРОЛЮ

Застосовано модель синтетичного контролю (SCM) для вимірювання втрат економічного потенціалу України, спричинених російсько-українською війною з 2014 р. Створено «синтетичну Україну» із зваженої комбінації (weighted average) 18 країн — регіональних аналогів на основі даних щодо ВВП на душу населення (ПКС) за період з 1996 по 2023 р. Ваги для кожної країни-донора відкалібровано так, щоб SCM точно відтворювала тенденцію економіки України до 2014 р. (з 1996 по 2013 р., тобто до початку війни). Ці довоєнні ваги потім використано в конструкції синтетичного контролю для періоду війни (2014—2023 рр.). Після 2014 р. ВВП на душу населення за ПКС значно відхиляється від контрфактичного сценарію. На 2021 р. розрив у ВВП досяг приблизно 1007 дол., або кумулятивно 44,6 млрд дол. ВВП за ПКС (що становить 6 % офіційного ВВП за ПКС того ж року). Використовуючи фактор конвертації від Світового банку, встановлено, що ця втрата є еквівалентною 325,6 млрд грн номінального ВВП за 2021 р. Сукупно конфлікт спричинив орієнтовну втрату в розмірі 1,1 трлн дол. номінального ВВП за ПКС у період з 2014 по 2023 р. Ваги донорів для синтетичного контролю зосереджено на Вірменії (0,54), Румунії (0,35) та Угорщині (0,10), які демонструють траєкторії зростання економіки, подібні до траєкторії України до війни. Перевірки на стійкість (робастність) підтверджують отримані результати: плацебо-тест для нестраждалої Вірменії не показує істотного розриву після 2014 р., а тести з виключенням окремих країн демонструють великий, стійкий після 2013 р. розрив, що свідчить про причинно-наслідковий ефект. Ці висновки підтверджують, що відхилення зумовлене саме втручанням, пов'язаним з війною, а не помилкою моделі. Визначена кумулятивна втрата виробництва збігається з величинами, наведеними в подібних дослідженнях на тему збитків через збройний конфлікт. Значний дефіцит ВВП підкреслює масштаб необхідного відновлення виробництва. Керівники органів влади можуть використовувати цей кількісно визначений розрив для планування галузевих заходів з відбудови.

**Ключові слова:** економічні втрати; розрив у ВВП; робастність; модель синтетичного контролю; війна.

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