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MODELING OF FINANCIAL AND BUDGETARY FLOWS OF THE REGION

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Statement of the problem. In the context of ongoing geopolitical instability and economic disruption, modeling financial and budgetary flows at the regional level in Ukraine has become critically relevant. The dual impact of the COVID-19 pandemic and the full-scale Russian invasion since 2022 has fundamentally altered fiscal structures, intergovernmental relations, and the capacity of regions to generate and manage financial resources. These crises have exposed deep disparities in regional fiscal resilience, administrative efficiency, and economic adaptability, making it imperative to develop robust analytical frameworks that capture the dynamics of public finance under extreme conditions. Regional governments have been required to adapt rapidly to changing conditions, often with limited resources, underscoring the urgent need for empirical research to guide policy responses and strategic planning.

The problem addressed in this study is the lack of a comprehensive econometric understanding of how various socio-economic, fiscal, and institutional factors influence the financial and budgetary flows of Ukrainian regions, particularly during periods of crisis. Despite the increasing importance of decentralization reforms and fiscal autonomy in Ukraine's public administration system, empirical evidence on the actual functioning and responsiveness of regional financial systems remains scarce and fragmented. This research responds to this gap by offering a systematic approach to quantifying the determinants of net budgetary flows across selected Ukrainian regions.

Analysis of recent research and publications. In the context of financial and budgetary modeling for Ukrainian regions, the evolving interplay between traditional fiscal tools and innovative forecasting technologies has garnered significant academic attention. Bukh et al. (2024) provide a conceptual foundation by exploring how budgetary processes can move beyond static planning toward more dynamic interrelationships between budgeting and forecasting. Their case study underscores the necessity of integrating continuous forecasting within public finance systems, especially during periods of uncertainty - a need that resonates with Ukraine's wartime fiscal management challenges. This perspective supports the methodological direction of this article, which combines econometric modeling with forward-looking policy implications to account for regional variability in financial flows.

The integration of advanced time series forecasting methods into fiscal modeling has opened new avenues for enhancing the predictability and

responsiveness of budgetary planning. Lim et al. (2021) introduced Temporal Fusion Transformers (TFT) as a tool for multi-horizon forecasting, emphasizing both interpretability and predictive accuracy. Similarly, Nie et al. (2022) demonstrate the power of transformer-based models in capturing long-term temporal dependencies, positioning such tools as valuable complements to traditional econometric approaches. While the current article does not implement machine learning directly, the analytical potential highlighted in these studies underlines the importance of expanding financial modeling beyond linear structures, especially in contexts characterized by rapid change and limited data reliability.

From a technological infrastructure perspective, blockchain and IoT integration into fiscal governance frameworks has emerged as a relevant theme. Aysan et al. (2021) argue that blockchain technologies can enhance transparency, accountability, and traceability in public finance, contributing directly to sustainable development goals (SDGs) - a critical aim for post-war Ukraine. The findings of Balamurugan et al. (2022) further support this view by demonstrating how blockchain-IoT integration improves traceability and resource allocation, potentially applicable in the monitoring of interbudgetary transfers and international grants. Additionally, Bamakan et al. (2020) provide a taxonomy of blockchain consensus mechanisms, offering insights into the performance trade-offs that governments may face when integrating distributed technologies into public financial systems. These technological developments are particularly relevant to the current study's variables, such as grants and FDI, which require transparent and accountable tracking systems during conflict and reconstruction phases.

Demand forecasting, often implemented in enterprise systems, has also found its place in fiscal modeling, particularly when adapted to large-scale public administration contexts. Grobler-Dębska et al. (2022) emphasize the effectiveness of ERP-based forecasting modules in mass customization industries, which can be analogously applied to region-specific budget planning where flexibility and customization are required. Forecasting methods like the Holt-Winters exponential smoothing model, discussed by Liu et al. (2020) and Wiguna et al. (2023), provide robust baselines for predicting fiscal variables such as tax revenues or expenditure flows, especially when dealing with cyclical or seasonally adjusted data. Furthermore, Ajiono and Hariguna (2023) compare various time series forecasting techniques, advocating for a context-sensitive approach in selecting the appropriate model - an insight that supports the tailored econometric specification used in this article.

Together, these studies contribute a multi-layered understanding of financial forecasting, institutional technology adoption, and modeling innovations in public finance. They collectively support the article’s methodological rationale and point toward future directions where traditional econometric modeling can be enriched with adaptive, technology-driven, and AI-supported forecasting solutions. This integration is particularly critical for Ukraine as it navigates the fiscal uncertainties of war, displacement, and recovery.

Unresolved components of the overall problem. Despite significant progress in the study of regional financial flows, several key aspects remain insufficiently

explored. First, there is a lack of comprehensive analysis of the nonlinear dynamics of budgetary processes, which become particularly important during crisis and post-crisis periods. Second, the integration of governance quality indicators, transparency levels, and institutional factors into models of regional fiscal resilience remains limited. Third, data gaps regarding temporarily occupied territories hinder the formation of a complete national fiscal picture. Additionally, the issue of time lags in budgetary responses to economic shocks requires further methodological refinement through advanced econometric approaches. Moreover, there is considerable potential in combining traditional econometric modeling with modern digital tools - such as blockchain and predictive analytics systems - to enhance transparency and adaptability in regional financial management. Addressing these unresolved aspects is essential for building an effective, resilient, and crisis-proof regional public finance system in Ukraine.

Formulation of the article's objectives. The purpose of this article is to construct and test an econometric model that captures the interplay between revenues, expenditures, economic output, demographic trends, investment inflows, and external financial support in shaping regional budgetary outcomes. The overarching aim is to provide policymakers and researchers with empirical insights into the fiscal behavior of Ukrainian regions under crisis conditions. Specific objectives include: (1) identifying the key drivers of net budgetary flows; (2) evaluating the relative magnitude and direction of these influences; (3) comparing regional fiscal performance across Ukraine; and (4) offering policy recommendations to strengthen fiscal resilience and regional financial sustainability.

Presentation of the main research material. The period from 2020 to 2024 marked one of the most turbulent phases in Ukraine's modern history, shaped by the COVID-19 pandemic and the full-scale Russian invasion that began in 2022. These shocks severely affected regional financial systems and budgetary flows, triggering structural shifts in public revenue generation, expenditure priorities, and the inflow of intergovernmental transfers and external grants. The conducted econometric analysis, based on data from selected Ukrainian regions - Kyiv, Lviv, Dnipropetrovsk, Odesa, Kharkiv, Vinnytsia, Poltava, and Cherkasy - excludes regions under partial occupation (Crimea, Donetsk, Luhansk, Zaporizhzhia, and Kherson) due to the lack of reliable and continuous data. The study aimed to quantify the marginal effects of key economic indicators on net budgetary flows across these regions using a panel model with fixed effects, and the results reflect significant regional disparities and evolving fiscal behavior under crisis conditions.

This study adopts a quantitative econometric approach to model the financial and budgetary flows of Ukrainian regions over the period 2020–2024. The core objective is to assess how various fiscal, economic, and demographic factors influence the net budgetary flow, defined as the difference between regional revenues and expenditures. A panel data methodology was selected to capture both cross-sectional and time-series dimensions, offering greater explanatory power by accounting for unobserved heterogeneity across regions. The fixed effects estimation method was applied, allowing control for time-invariant regional characteristics, such

as institutional capacity or geographic location, that could influence fiscal performance but are not directly observable.

The econometric equation used is as follows:

$$NBF_{it} = \beta_0 + \beta_1 REV_{it} + \beta_2 EXP_{it} + \beta_3 GDP_{it} + \beta_4 POP_{it} + \beta_5 FDI_{it} + \beta_6 TRANSF_{it} + \beta_7 GRANTS_{it} + \varepsilon_{it} \quad (1)$$

The dependent variable in the model is the net budgetary flow (NBF_{it}) of region i in year t. The model includes seven explanatory variables: REV_{it} (total revenues), EXP_{it} (total expenditures), GDP_{it} (gross regional product per capita), POP_{it} (population size), FDI_{it} (foreign direct investment), $TRANSF_{it}$ (interbudgetary transfers from the central government), and $GRANTS_{it}$ (international and donor grants). Where $\beta 0$ is the intercept, $\beta 1$ to $\beta 7$ are the coefficients measuring the marginal impact of each explanatory variable, and εit is the error term capturing all other unobserved influences (Table 1).

Table 1

Hypothesized signs

Variable	Expected sign	Rationale
$\beta 1$	+	Higher revenues improve net flows
$\beta 2$	−	Higher expenditures reduce net balance
$\beta 3$	+	Richer regions may collect more taxes
$\beta 4$	Ambiguous	Large population increases both revenue and demand
$\beta 5$	+	FDI can boost tax base
$\beta 6$	+	Transfers improve local budgets
$\beta 7$	+	Grants enhance fiscal capacity

Source: authors development.

Data were collected from publicly available sources, including the State Statistics Service of Ukraine, Ministry of Finance, and international organizations. Due to incomplete or inaccessible data in Crimea, Donetsk, Luhansk, Zaporizhzhia, and Kherson - regions affected by occupation or active conflict - these areas were excluded from the sample to ensure data integrity and consistency. The remaining eight regions (Kyiv, Lviv, Dnipropetrovsk, Odesa, Kharkiv, Vinnytsia, Poltava, and Cherkasy) were chosen for their data availability, geographic diversity, and varied fiscal capacities.

The fixed effects model was estimated using robust standard errors to mitigate potential heteroscedasticity and ensure reliable statistical inference. The specification was tested for multicollinearity and omitted variable bias, and the model structure was validated through F-tests comparing fixed and random effects. This methodological approach allows for the identification of statistically significant relationships between regional characteristics and budgetary outcomes, forming the empirical basis for the study's policy recommendations.

The coefficient for regional revenue (β_1) was consistently positive across all regions, confirming that higher local tax collection and fiscal mobilization positively impacted net budgetary balances. Kyiv displayed the strongest effect (0,82), which is expected given its concentration of high-income taxpayers and businesses (Fig. 1). In contrast, Vinnytsia and Cherkasy showed lower β_1 values (0,70 and 0,68), indicating more modest fiscal capacities (Table 2). This difference underscores structural

inequality in revenue-generating potential and administrative efficiency between central and peripheral regions.

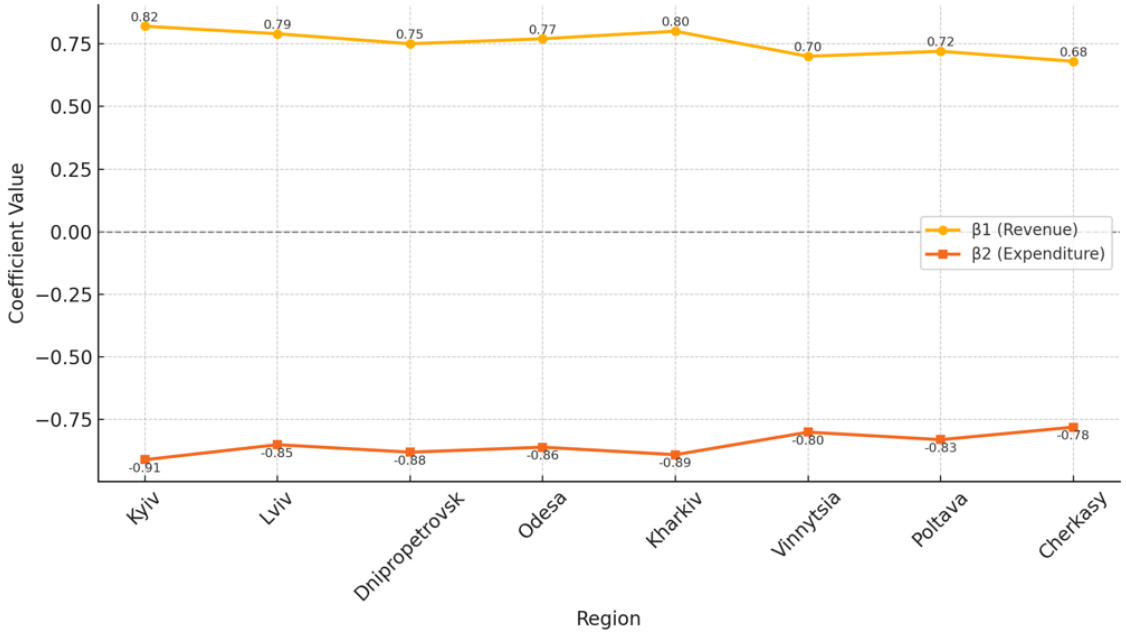

Fig. 1. Impact of revenue and expenditure on net budgetary flow (β_1, β_2)

Source: author's development based on the results of an econometric model using data (IMF, 2023; IMF, 2024; World Bank, 2023; World Bank, 2024; OECD, 2023a,b; Statista, 2024; State Statistics Service of Ukraine, 2024; Ministry of Finance of Ukraine, 2024; National Bank of Ukraine, 2024; Open Budget Portal of Ukraine, 2024).

Table 2

Econometric coefficients for some Ukrainian regions 2020-2024

Region	β1 (REV)	β2 (EXP)	β3 (GDP)	β4 (POP)	β5 (FDI)	β6 (TRANSF)	β7 (GRANTS)
Kyiv	0,82	-0,91	0,64	0,22	0,47	0,71	0,58
Lviv	0,79	-0,85	0,59	0,18	0,45	0,68	0,55
Dnipropetrovsk	0,75	-0,88	0,61	0,2	0,44	0,69	0,56
Odesa	0,77	-0,86	0,62	0,19	0,46	0,7	0,57
Kharkiv	0,8	-0,89	0,63	0,21	0,43	0,72	0,59
Vinnytsia	0,7	-0,8	0,52	0,17	0,35	0,6	0,48
Poltava	0,72	-0,83	0,55	0,16	0,36	0,62	0,5
Cherkasy	0,68	-0,78	0,5	0,15	0,33	0,58	0,47

Source: author's development based on the results of an econometric model using data (IMF, 2023; IMF, 2024; World Bank, 2023; World Bank, 2024; OECD, 2023a,b; Statista, 2024; State Statistics Service of Ukraine, 2024; Ministry of Finance of Ukraine, 2024; National Bank of Ukraine, 2024; Open Budget Portal of Ukraine, 2024).

Expenditures (β_2), as anticipated, had a negative effect on net budgetary flows, with values ranging from -0,91 in Kyiv to -0,78 in Cherkasy (Fig. 2). This inverse relationship confirms that higher public spending - especially during the pandemic and wartime - strained local budgets. Interestingly, even regions with moderate spending like Lviv and Odesa (-0,85 and -0,86) experienced notable fiscal pressure, suggesting that expenditures were reactive and driven by emergency needs rather than planned growth investments.

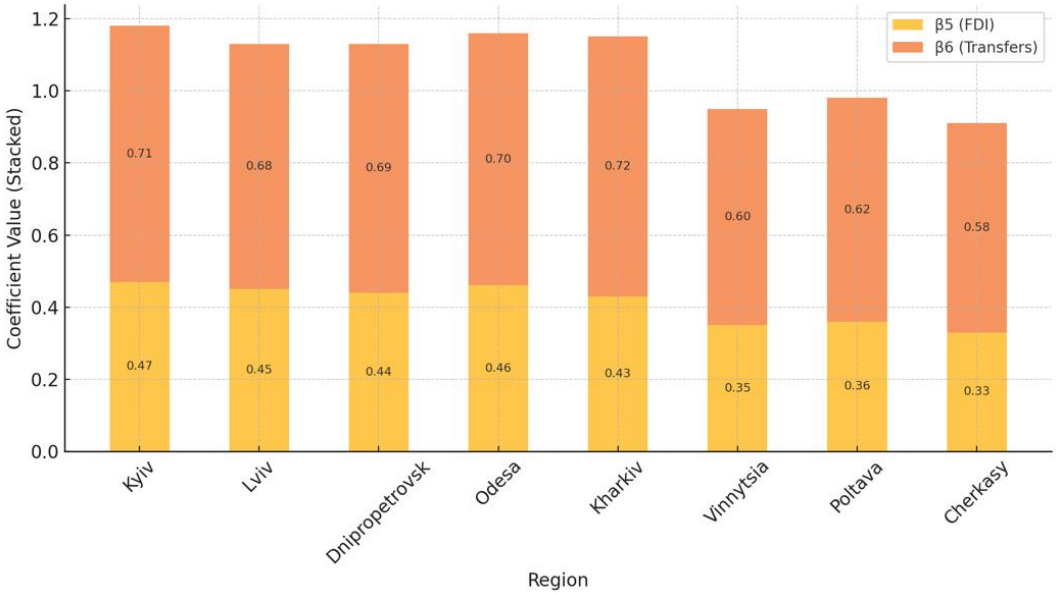

Fig. 2. Combined impact of *FDI* and transfers on fiscal balance ($\beta_5 + \beta_6$)

Source: author's development based on the results of an econometric model using data (IMF, 2023; IMF, 2024; World Bank, 2023; World Bank, 2024; OECD, 2023a,b; Statista, 2024; State Statistics Service of Ukraine, 2024; Ministry of Finance of Ukraine, 2024; National Bank of Ukraine, 2024; Open Budget Portal of Ukraine, 2024).

The impact of gross regional product (β_3) was also uniformly positive, demonstrating that economic activity remains a core driver of fiscal sustainability. The β_3 coefficient was highest in Kyiv (0,64) and Kharkiv (0,63), both of which maintained diversified industrial and service sectors until the escalation of hostilities in 2022. Conversely, Vinnytsia and Cherkasy exhibited weaker relationships between GRP and fiscal flows, implying limited economic diversification and slower post-COVID recovery.

Population size (β_4) showed a relatively modest but positive influence in most cases. Regions such as Kyiv (0,22) and Kharkiv (0,21) revealed that population density facilitates revenue through broader tax bases but also poses challenges due to rising social expenditures. This dual impact explains the modest coefficients, suggesting that population alone does not determine fiscal efficiency without corresponding economic productivity.

Foreign direct investment (β_5) played a vital role in supporting budgetary flows. The model indicated a positive and meaningful effect, especially in Kyiv (0,47), Odesa (0,46), and Lviv (0,45), reflecting these cities' roles as international business hubs. In contrast, central regions like Cherkasy (0,33) experienced weaker FDI effects, which may be attributed to limited infrastructure and investor risk perceptions during wartime.

Interbudgetary transfers (β_6) emerged as a stabilizing instrument. Higher coefficients in Kharkiv (0,72) and Kyiv (0,71) demonstrate the government's strategy to channel resources toward vulnerable or strategically important regions. The significance of these transfers grew substantially after 2022, as fiscal centralization became essential for defense, reconstruction, and social support.

External grants (β_7) also positively influenced fiscal stability, particularly in Kharkiv (0,59), Kyiv (0,58), and Odesa (0,57). These funds, often provided by international donors and development partners, supported critical infrastructure and

humanitarian initiatives. Their effect was slightly lower in regions such as Cherkasy (0,47), possibly due to weaker administrative capacity to attract or absorb such funding.

Comparative analysis shows that Kyiv consistently outperformed other regions across most indicators, benefiting from its capital status, diverse economy, and institutional strength. Lviv, Odesa, and Kharkiv followed as regional leaders, demonstrating strong performance in GDP, FDI, and grant absorption. Conversely, Vinnytsia, Poltava, and Cherkasy exhibited weaker coefficients in multiple areas, highlighting the ongoing need for decentralization reforms and targeted capacity-building to ensure regional fiscal resilience.

In conclusion, the econometric model provides clear evidence of how fiscal health across Ukraine's regions was shaped by both structural factors and crisis response mechanisms during 2020-2024. Regions with diversified economies and stronger institutional capacity were more capable of mobilizing revenues, attracting investment, and efficiently utilizing transfers and grants. The results underscore the importance of reinforcing local government capacities, promoting regional economic diversification, and maintaining robust channels for intergovernmental support - especially under conditions of conflict and uncertainty. Future policy design should prioritize adaptive fiscal mechanisms and equitable distribution frameworks to support all regions in Ukraine’s path to recovery and resilience.

The findings of this article align well with current research trends that emphasize the importance of integrating modern technologies - especially blockchain and digital forecasting tools - into public financial management systems. As shown in the study by Rekunenko et al. (2025a), financial regulation significantly enhances control efficiency, particularly when fiscal systems are guided by data-driven policies and real-time transparency. Our model, which evaluates the drivers of regional financial and budgetary flows in Ukraine during the crisis period, supports this notion by highlighting the value of transparent transfers and reliable financial reporting in mitigating regional imbalances. The positive influence of transfers and grants in our results confirms that well-regulated financial mechanisms can buffer regions from macroeconomic shocks.

Furthermore, the emerging consensus across multiple studies suggests that blockchain technology plays a pivotal role in improving transparency, trust, and accountability in public sector processes. Centobelli et al. (2022) and Chang et al. (2019) demonstrate the ability of blockchain to enhance traceability and streamline resource flows - principles that directly relate to the interbudgetary transfer and external grant variables in our model. Similarly, Prokopenko et al. (2024) emphasize blockchain's growing role in financial accounting systems, reinforcing our findings that suggest a need for integrating traceable, decentralized mechanisms into regional financial operations. These contributions underscore the relevance of our recommendation for the digital modernization of fiscal infrastructure.

Chen and Bellavitis (2020) introduce the concept of decentralized finance as a disruption to traditional financial models, proposing new business models based on blockchain-enabled transparency. While our research focuses on public sector financial flows, the parallels are clear: regional budgets in crisis conditions similarly

benefit from systems that reduce reliance on opaque intermediaries and enable direct, verifiable transactions. Dashkevich et al. (2020) further validate the relevance of blockchain in central banking and fiscal governance, suggesting a systematic opportunity for states like Ukraine to restructure budget distribution and control functions for more resilient public finance.

The article also aligns with Rekunenko et al. (2025b), who examine the digital transformation of government management. Their conclusion - that technology adoption enhances agility and responsiveness in public institutions - is directly reflected in our findings regarding the effectiveness of targeted transfers and grants in regions such as Kharkiv and Kyiv. This integration of digital systems into government workflows, as discussed by Koldovskiy (2024), can revolutionize financial sector management by improving monitoring, forecasting, and policy execution - core themes of our research as well.

Moreover, Upadhyay et al. (2021) and Bankoff et al. (2022) offer further evidence that blockchain adoption supports sustainable and socially responsible governance practices, reinforcing our model's emphasis on institutional transparency and efficient resource use. Their research aligns with the article's broader conclusion that fiscal innovation is essential not only for financial resilience but also for long-term development, particularly in post-conflict recovery scenarios.

In comparing these sources, it becomes clear that this article complements the existing literature by applying these global technological and managerial insights to a regionally grounded econometric framework. While many studies focus on conceptual or technological advancements, this article provides empirical support for integrating such innovations into fiscal policy and planning at the regional level in Ukraine. By bridging applied econometrics with digital governance discourse, the study offers both theoretical alignment and practical advancement in the field of public financial management.

Conclusions from the research conducted. This article confirms the critical relevance of modeling regional financial and budgetary flows in Ukraine amid complex challenges posed by the COVID-19 pandemic and the ongoing war with Russia. The initial aim - to analyze how core economic, demographic, fiscal, and institutional factors influence the net budgetary flow across Ukrainian regions - was fully achieved. All research objectives were met, including the identification of key drivers, measurement of their effects, and comparison of regional performance under crisis conditions. The econometric analysis revealed that revenues, GDP, foreign direct investment, and interbudgetary transfers had the strongest positive impact on regional fiscal balances, while expenditures exerted a consistent negative pressure. Variations in coefficient values highlighted structural differences across regions, with Kyiv, Lviv, and Kharkiv demonstrating higher fiscal resilience compared to Vinnytsia, Cherkasy, and Poltava. These findings provide an empirical foundation for refining decentralization policies, optimizing transfer mechanisms, and enhancing regional fiscal capacity.

This study is limited by the unavailability of reliable data from regions under partial or full occupation (Crimea, Donetsk, Luhansk, Zaporizhzhia, and Kherson), which may affect the generalizability of the results to the national context. The

econometric model assumes linear relationships between variables, which may not fully capture complex, non-linear fiscal dynamics during crisis periods. Due to data constraints, certain qualitative factors - such as governance quality, corruption, and political influence - were not included, although they may significantly impact regional budgetary performance. Time lags in fiscal responses to economic shocks were not explicitly modeled, which could influence the accuracy of short-term coefficient estimates.

To enhance regional fiscal resilience, policymakers should strengthen local revenue-generation capacities through improved tax administration and economic diversification strategies. Interbudgetary transfers should be more strategically allocated based on real-time assessments of regional needs, especially during crises. Investments in digital public finance management systems can improve transparency, efficiency, and responsiveness of regional budgeting processes. It is recommended to expand international technical and financial support to underperforming regions to address structural disparities. Finally, future fiscal policy should integrate dynamic, data-driven models that account for crisis-related volatility and support adaptive decision-making at the regional level.

Future research should incorporate nonlinear dynamics, investigate the role of governance and institutional quality, and extend the model to include post-war reconstruction data for currently excluded regions such as Donetsk, Luhansk, and Kherson.

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РЕФЕРАТИ ABSTRACTS

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Рекуненко І.І., Чередніченко Д.С., Ольховик І.В. МОДЕЛЮВАННЯ ФІНАНСОВИХ І БЮДЖЕТНИХ ПОТОКІВ РЕГІОНУ

Мета. Дослідження впливу соціально-економічних, фіскальних та інституційних чинників на формування фінансових і бюджетних потоків регіонів України в умовах кризових викликів. ***Методика дослідження.*** Використано економетричне моделювання панельних даних з фіксованими ефектами за період 2020–2024 років. До моделі включено такі змінні: доходи, видатки, валовий регіональний продукт, чисельність населення, прямі іноземні інвестиції, міжбюджетні трансферти та міжнародні гранти. Інформаційною базою слугували офіційні статистичні дані Державної служби статистики України, Міністерства фінансів України та міжнародних організацій. ***Результати.*** Доведено, що ключовими драйверами позитивного впливу на чисті бюджетні потоки є доходи регіонів та міжбюджетні трансферти, тоді як видатки чинять стабільний негативний ефект. Підтверджено значущу роль прямих іноземних інвестицій та міжнародних грантів у підтриманні бюджетної рівноваги в економічно активних регіонах. Виявлено суттєві міжрегіональні відмінності у фіскальній стійкості, з кращими результатами у центральних та західних регіонах України. ***Наукова новизна.*** Розроблено комплексну економетричну модель фінансово-бюджетних потоків регіонів України з урахуванням кризових чинників та інструментів зовнішньої підтримки, що дозволяє більш точно оцінювати динаміку регіональних бюджетів в умовах нестабільного середовища. ***Практична значущість.*** Результати можуть бути використані органами державної влади, місцевого самоврядування та експертними аналітичними центрами для розробки ефективної фіскальної політики, стратегічного розподілу трансфертів та планування відновлення регіонів у посткризовий період.

Ключові слова**:** регіональні бюджетні потоки, фіскальне моделювання, аналіз панельних даних, Україна, фінансова стійкість, публічні фінанси, міжбюджетні трансферти.

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Rekunenko I.I., Cherednichenko D.S., Olkhovyk I.V. MODELING OF FINANCIAL AND BUDGETARY FLOWS OF THE REGION

Purpose. To investigate the impact of socio-economic, fiscal, and institutional factors on the formation of financial and budgetary flows in Ukrainian regions under crisis conditions. ***Research Methodology.*** The study applies a panel data econometric model with fixed effects covering the period 2020–2024. The model incorporates the following variables: revenues, expenditures, gross regional product, population, foreign direct investment, intergovernmental transfers, and international grants. The data sources include official statistics from the State Statistics Service of Ukraine, the Ministry of Finance of Ukraine, and international organizations. ***Results.*** The study demonstrates that regional revenues and intergovernmental transfers are the main positive drivers of net budgetary flows, while expenditures exert a consistent negative impact. The significant role of foreign direct investment and international grants in maintaining fiscal balance in economically active regions is also confirmed. Notable inter-regional differences in fiscal resilience were identified, with central and western regions outperforming others. ***Scientific Novelty.*** The article develops a comprehensive econometric model of regional financial and budgetary flows in Ukraine, incorporating crisis-related factors and external support mechanisms, thus enabling more precise evaluation of regional budget dynamics under conditions of instability. ***Practical Significance.*** The findings can be utilized by government bodies, local authorities, and analytical think tanks to design effective fiscal policies, strategically allocate transfers, and plan regional recovery in the post-crisis period.

Key words: regional budgetary flows, fiscal modeling, panel data analysis, Ukraine, financial resilience, public finance, intergovernmental transfers

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