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EXPORT OF DIGITAL SERVICES AS A CHANNEL FOR OVERCOMING MACROECONOMIC DISBALANCES

ЕКСПОРТ ЦИФРОВИХ ПОСЛУГ ЯК КАНАЛ ПОДОЛАННЯ МАКРОЕКОНОМІЧНИХ ДИСБАЛАНСІВ

Introduction. *War-related disruption increases the relevance of digitally deliverable services, but their macroeconomic role requires empirical qualification.* ***Purpose.*** *To assess services exports as a recovery channel and discuss institutional options for digital micro-exporters.* ***Methods.*** *Ward clustering of 50 recovery episodes, principal component analysis and Bayesian NARDL/ECT estimation are combined. The Ukrainian sample covers 1996–2023; forecasts compare inertial and intervention paths.* ***Results.*** *The Ukrainian services-export adjustment coefficient is −0.7476, compared with −0.3374 in the benchmark. The modernisation component has a marginal return of +2.65. Scenario estimates reach 39.87% and 41.09% of GDP in 2031. Limited sample size constrains precision.* ***Conclusion.*** *Digital micro-export taxation and programmable settlement tools are proposed for pilot testing. The estimates concern aggregate services exports and do not identify the causal effects of these instruments.*

Keywords**:** *digital services, macroeconomic disbalances, structural transformation, export-led recovery, e-hryvnia, post-conflict reconstruction, monetary sovereignty.*

Анотація. *У статті досліджено роль експорту послуг як каналу подолання макроекономічних дисбалансів та розглянуто інституційні можливості розвитку цифрового мікроекспорту в умовах воєнних руйнувань і повоєнного відновлення. Актуальність проблеми зумовлена потребою у надходженні валютної виручки за обмеженої пропускної спроможності фізичної логістики та необхідністю розмежування потенціалу цифрових послуг і фактично оцінених макроекономічних залежностей. Мета дослідження полягає в оцінюванні реакції експорту послуг на структурні чинники та визначенні меж використання цих оцінок для обґрунтування інституційних пропозицій. Методичний підхід поєднує кластеризацію 50 епізодів відновлення методом Варда, аналіз головних компонент і байєсівське оцінювання нелінійної авторегресійної моделі з розподіленими лагами та корекцією помилки. На основі 32 ефекторів виділено п'ять компонентів, які пояснюють 68,8 % дисперсії. Українська частина дослідження охоплює річні спостереження за 1996–2023 роки. Установлено, що коефіцієнт корекції помилки в рівнянні експорту послуг України становить −0,7476 проти −0,3374 в еталонному кластері. Гранична віддача компоненти структурно-технологічної модернізації дорівнює +2,65, а коефіцієнт її квадратичного члена становить +1,5481. Водночас компоненти зовнішньої стійкості та монетарного суверенітету мають від'ємні оцінені граничні віддачі. Сценарне зіставлення на 2031 рік дає 39,87 % ВВП за інерційною траєкторією та 41,09 % за траєкторією втручання. Ці значення характеризують умовні результати моделі, а не доведений ефект конкретного податкового чи платіжного інструмента. Запропоновано дослідити автоматизоване справляння збору з цифрового мікроекспорту та програмовані розрахунки із застосуванням е-гривні як напрями пілотного тестування. Наголошено, що залежність оцінено для сукупного експорту послуг, а не окремо для його цифрового сегмента. Короткі часові ряди, помірна стійкість кластеризації та невисока скоригована якість рівняння обмежують точність прогнозів. Подальші дослідження мають спиратися на дезагреговані дані, перевірку чутливості та пряме оцінювання витрат і наслідків запропонованих механізмів.*

Ключові слова: *цифрові послуги, макроекономічні дисбаланси, структурна трансформація, експортно-орієнтоване відновлення, е-гривня, післявоєнна відбудова, монетарний суверенітет.*

Statement of the Problem. Post-conflict stabilisation requires activities that can generate foreign-exchange receipts while the economy restores its productive capacity. Digitally deliverable services are relevant to this problem because their cross-border delivery can be less dependent on physical freight infrastructure than the export of goods [10; 16]. Their contribution nevertheless depends on human capital, connectivity and functioning payment arrangements. The policy task is to assess these conditions and test potential institutional mechanisms rather than assume that digital delivery alone guarantees macroeconomic stabilisation.

The practical relevance of this problem extends beyond the volume of export receipts. Recovery policy must consider how exporters obtain reliable electricity and telecommunications, retain skilled workers, receive cross-border payments and comply with tax and reporting obligations. Digital delivery can reduce dependence on the physical movement of goods, but it does not remove infrastructure, security or institutional constraints. Accordingly, services exports should be examined as one potentially important recovery channel rather than treated as an automatic substitute for manufacturing or infrastructure reconstruction [10; 16].

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A second issue concerns the level at which the available evidence is measured. The estimated outcome in this study is aggregate services exports relative to GDP, whereas the proposed institutional measures focus on digitally delivered services and small exporters. These categories overlap but are not identical. An aggregate relationship can motivate a hypothesis about the digital segment, yet it cannot establish that the same coefficient applies to software developers, professional-service providers and other exporters. This distinction is necessary to avoid attributing changes in the entire services sector to a particular digital activity.

A third unresolved issue is the translation of structural associations into policy design. A principal component summarises several correlated indicators; it is not a directly controllable tax rate, payment instrument or regulatory rule. Consequently, a positive association with modernisation does not, by itself, establish the effectiveness of an automatic levy or a programmable currency. The implementation question therefore concerns not only expected export growth but also compliance costs, access to settlement services and the distribution of burdens across small and large suppliers [1; 2; 12].

The research problem is thus to connect the estimated dynamics of the services-export equation with a transparent account of what those estimates can support. The article separates the macroeconomic assessment from the proposed institutional mechanisms and treats the latter as candidates for further testing. This approach makes the unresolved link between sectoral adjustment, digital delivery and operational policy instruments an explicit part of the analysis.

Analysis of Recent Research and Publications. Export-led recovery historically focuses on manufacturing. Thirlwall [15, p. 48] formalised the payments constraint. Rodrik [14, p. 102] warned against premature deindustrialisation, while Hausmann, Rodrik and Velasco [8, p. 2] insisted that a growth strategy target the single most binding constraint rather than a long list of reforms drawn up before any diagnosis.

Thirlwall's rule ties the sustainable growth rate to the income elasticity of export demand, and he built it for an economy exporting goods whose transport and tariff costs can be measured [15, p. 48]. Rodrik's objection to premature deindustrialisation rests on the claim that manufacturing raises productivity at a pace services rarely match [14, p. 102]. We accept the mechanics of both arguments and dispute their domain. Neither author considered an economy whose ports, rail and thermal generation lie damaged while its engineers keep billing foreign clients without interruption. Hausmann, Rodrik and Velasco supply the diagnostic logic we borrow, namely find the binding constraint first and design the reform afterwards [8, p. 2], yet they stop at qualitative sequencing. Our estimated marginal returns convert that sequencing into a ranked numerical ordering of structural components, and this is where our contribution to the recovery literature starts.

Economic impacts reveal themselves fast. The WTO [16, p. 15] shows how the digital revolution drives down the cost of trading services across borders; the IMF ties recovery outcomes to macroeconomic stabilisation, access to financing and institutional quality [9, p. 26]. CBDCs, explored by Ahnert et al. [1, p. 17], Bordo and Levin [3, p. 3] and Auer and Böhme [2, p. 95], reduce transaction frictions. The FATF [6, p. 107] and the OECD [13, p. 8] set the regulatory parameters of digital settlement.

Digital-trade scholarship runs in a parallel channel with little contact with the recovery literature. The WTO documents how falling communication costs have cut the price of trading services and expects the services share of world trade to keep rising [16, p. 15]. The IMF's post-conflict chapter links recovery outcomes to stabilisation, financing and institutional quality, treating the three as complements [9, p. 26]. Digital Tiger 2024 records the scale and export orientation of the Ukrainian IT industry [10, p. 7]. These studies share a descriptive posture: they measure the sector, or they measure recovery, but they do not estimate how one responds to the other inside one dynamic system. We estimate that response directly.

On the monetary side, Ahnert and co-authors classify the channels through which a central bank digital currency alters bank funding and payment efficiency [1, p. 17]; Bordo and Levin argue that a well-designed digital currency can become the primary medium of exchange and sharpen monetary control [3, p. 3]; Auer and Böhme dissect the architectures open to a retail design and show how that choice decides who carries settlement risk [2, p. 95]. All three remain inside monetary economics. We move the same instruments into a structural-modernisation role, since in our estimates a programmable currency matters less as a monetary innovation than as a device that lowers the transaction cost of a cross-border services contract, and that effect enters our equations through the modernisation component rather than through monetary sovereignty.

The unresolved issue is the link between three analytical levels: the adjustment of aggregate services exports, the specific conditions facing digitally delivered services, and the effects of concrete fiscal or payment instruments. Existing recovery and digital-trade studies provide relevant frameworks, but an estimated macroeconomic association does not identify the effect of a particular instrument on digital exporters. This article addresses the first level quantitatively and uses the results to formulate testable proposals at the other two levels, while retaining the distinction between empirical estimates and institutional hypotheses.

Aim of the Article. The aim is to evaluate the response of services exports to macroeconomic structural components and to assess the implications for digital services as a potential recovery channel. The article identifies dynamic adjustment patterns, examines the model's limitations and develops proposals for testing tax and digital-settlement mechanisms without treating their effects as already established.

Research Methods.

Data, Benchmark Selection and Principal Components.

We cover 50 recovery episodes. The observations are annual, which avoids temporal disaggregation. Nine macroeconomic disbalance indicators were clustered across a five-year stabilisation window by Ward's method, and the benchmark emerged at k=6 as Cluster 4, which comprises 11 episodes. An inflation disbalance of 2.33 %, a current account surplus of 3.67 % of GDP and real growth of 5.78 % define it.

Several design choices deserve exposition. We standardised the nine indicators before clustering, because inflation measured in per cent and reserves

measured in months of imports are not comparable on a raw scale, and we chose Ward's linkage with a Euclidean metric since it minimises within-cluster variance and therefore matches our interest in homogeneous recovery profiles. The silhouette coefficient rises from 0.134 at k=3 through 0.162, 0.176 and 0.196 at k=6, then falls to 0.192 at k=7, so the partition we selected sits at a local maximum rather than on a pronounced peak. A cophenetic correlation of 0.735 indicates moderate fidelity of the dendrogram to the original distances, and agreement with a k-means partition of the same data reaches only 56 %. The benchmark cluster is a defensible grouping, not a sharply separated one, and we treat it as such throughout.

On 32 effectors for that cluster we ran a principal component analysis, yielding an adequate KMO of 0.710, yet the minimum per-indicator KMO dropped to 0.273, so several indicators contribute weakly and the extraction stays partly fragile. Five components explain 68.8 % of variance. PC1 represents monetary sovereignty strength (27.2 %), PC2 denotes the fiscal capacity of the state (14.6 %), PC3 captures external resilience (12.0 %), PC4 signifies structural and technological modernisation (8.2 %), and PC5 reflects the quality of institutional capital (6.9 %).

The extraction rests on a window running from five years before to fourteen years after the start of each episode, which yields 220 observations across the 11 episodes, with 5.3 % of values interpolated. Bartlett's test of sphericity rejects an identity correlation matrix (χ^2 = 18 411.6, df = 496, p < 0.001), so the correlation structure holds enough common variance for extraction to be meaningful. The Kaiser criterion returns nine components; we retained five and applied an orthogonal Varimax rotation, which loads each component on a distinct group of indicators and makes the economic labels above defensible rather than decorative. Ukrainian data cover 1996–2023, giving 28 annual observations and 24 first differences, with 2.7 % of values interpolated.

Nonlinear Model and Bayesian Estimation.

Using an exponent $\kappa = 2.5$ selected by grid search to capture asymmetric responses, we estimate a nonlinear autoregressive distributed lag model with an error correction term (NARDL/ECT). The equation carries quadratic, logarithmic and power terms:

$$\Delta y_{i,t} = \alpha + \lambda ECT_{i,t-1} + \sum_{j=1}^{5}\sum_{L=0}^{3}[\beta_{jL} PC_{j,t-L} + \gamma_{jL} PC_{j,t-L}^2]$$

$$+\sum_{j=1}^{5}[\delta_j ln\left(1+\left|PC_j\right|\right)+\theta_j \mid PC_j \mid^{\kappa}]+\varepsilon_{i,t}$$

Here, $\Delta y_{i,t}$ is the target's first difference, λ is the adjustment speed, $ECT_{i,t-1}$ is the error correction term, PC_j are the extracted components, and $\varepsilon_{i,t}$ is the stochastic error. Estimation relied on Markov chain Monte Carlo (MCMC) with a Metropolis–Hastings algorithm and 240 000 posterior draws [7, p. 460].

The nonlinear part of the specification needs a precise statement, since it carries our central result. Each component enters at lags 0 to 3, in levels and in squares, which lets the response change slope as a component moves away from its mean instead of holding one gradient across the whole range. Two further terms enter without lags. The logarithmic term compresses large deviations and so represents saturation, while the power term amplifies them and so represents acceleration; holding both in the same equation lets the data decide which regime applies to each circuit. We did not assume the exponent: a grid search selected κ = 2.5, a value lying between quadratic and cubic response. A linear specification would have forced the modernisation effect onto a single constant slope and would have concealed exactly the curvature we report below.

Convergence was checked rather than assumed. Four chains of 90 000 iterations, with the first 30 000 draws discarded as burn-in, leave 240 000 posterior draws per equation; the maximum Gelman–Rubin statistic stays at or below 1.016, the minimum effective sample size is 261, and acceptance rates settle between 0.21 and 0.35 after adaptive step scaling [7, p. 460]. Priors are Normal(0; 2.5) on structural coefficients and InvGamma(2; 1) on shock variance, which is weakly informative at the scale of standardised components. Transfer to Ukraine used the benchmark posteriors as informative priors at scale 2, midway between full transfer at scale 1 and the nearly uninformative setting at scale 4, together with a parsimonious specification of a constant, the error correction term and the ten strongest regressors, at most 12 parameters on 24 first differences. Maximum $\hat{R}$ for the Ukrainian equations is 1.002, with acceptance rates from 0.24 to 0.30.

Presentation of the Main Research Material.

Adjustment of the Services-Export Circuit.

For services export the adjustment speed is estimated at $\lambda = -0.7476$, with a 95 % highest posterior density interval of [-1.1106; -0.3872]. Sector adjustment outpaces the benchmark cluster's rate of -0.3374, and the gap of 0.4102 is the largest among the six circuits we estimate. In-sample fit reaches an R-squared of 0.710, while an adjusted R-squared of only 0.395 and a Theil coefficient of 0.536 keep that fit modest once the parameter count is charged against the short sample.

Transfer of benchmark information did not assist every circuit equally. For inflation it narrowed the highest posterior density interval by 35.6 % and for investment by 12.5 %, whereas for services export the narrowing figure is -40.2 %, which means the interval widened once Ukrainian data contradicted the benchmark prior. We read that widening as informative rather than as failure. The Ukrainian services circuit does not behave like the average of the benchmark episodes, a conclusion consistent with the 0.4102 difference in adjustment speed and with our argument that digitally deliverable services occupy a larger structural position here than in the historical episodes.

The exchange-rate equation, we must state, fitted poorly, with an adjusted R-squared of -0.759 and a Theil coefficient of 0.818. It serves an indicative purpose only and must not be used for policy inference.

Our central finding concerns the response of services exports to modernisation (PC4). The marginal return is positive at +2.65, and the coefficient on the quadratic term $PC4^2$ reaches +1.5481. Returns accelerate rather than plateau. As digital infrastructure coalesces, network effects multiply export capacity, so digitally deliverable services work as a scalable recovery engine.

Both signs carry economic content worth stating separately. The linear return of +2.65 says that one standard deviation of additional structural and technological modernisation raises the services-export share of GDP;

Table 1

Marginal returns of macroeconomic circuits to components

Circuit	PC1	PC2	PC3	PC4	PC5
Inflation	0.00	-0.50	0.52	0.00	-0.18
Real GDP growth	-0.96	0.00	0.00	3.80	2.64
Investment	1.00	-0.34	-6.37	5.33	0.00
Services export	-2.38	0.00	-3.74	2.65	0.00

Source: author's estimates from the component-based models described in Research Methods

the positive quadratic coefficient of +1.5481 says the second unit of modernisation buys more than the first. Increasing returns of this shape are uncommon in macroeconomic estimates, and the mechanism behind them is plain enough: fibre capacity, electronic identity, payment rails and an engineering pool working in English are complements, so each element added raises the productivity of those already installed. The same component earns +3.80 in the growth circuit and +5.33 in the investment circuit, and on the normalised aggregate measure it scores +1.00 against -0.77 for external resilience. Modernisation is the only component whose return is positive in every circuit where it enters at all.

A genuine policy trade-off exposes itself here. External resilience (PC3) exerts a negative marginal return on services export of -3.74, underpinned by a significant coefficient of -3.7427 (z = 2.5). Monetary sovereignty (PC1) enters the circuit negatively at -2.38. We read it thus: orthodox policy builds reserve buffers and tightens the domestic monetary circuit to shield the wider economy, yet those same interventions suppress the agility of service exporters, since a cross-border transaction is inseparable from a foreign exchange transaction carrying extra fees and unfavourable rates [2, p. 95].

The negative sign on external resilience is not an argument against holding reserves. Reserve accumulation, import compression and administrative limits on capital movement all operate by widening the wedge between the domestic and the external monetary circuit, and a service exporter lives inside that wedge: every invoice is settled abroad, converted at a regulated rate and taxed by the spread. PC3 earns +7.85 in the goods trade balance while it costs -3.74 in services exports, so the two circuits pull in opposite directions, and any external-stability package therefore has a price expressed in forgone service exports. Monetary sovereignty behaves in a comparable way at -2.38. Tighter control of the domestic circuit stabilises prices and supports investment, where PC1 enters at +1.00, but it raises the unit cost of moving small sums across the border, and micro-exporters bear that cost in full. Read against these returns, the policy vector our equations imply is a mild annual reduction of 0.033 standard deviations in PC1 and a larger reduction of 0.231 in PC3, not the abandonment of either.

Institutional innovations.

Addressing these frictions requires interventions that stimulate PC4. Our equations give the component a policy increment of +0.300 standard deviations per year.

An automatic levy of 3-5 % on micro-exports of digital services, with banks acting as tax agents, is our first proposal. Declaration-based taxation leaves IT micro-exporters facing high administrative barriers. Embedding the liability into the clearing process widens the formal export tax base and strips out bureaucratic friction; the OECD finds that collection through a limited number of capable intermediaries carries markedly lower administrative costs and higher compliance than collection from millions of small suppliers [12, p. 46]. The increment of +0.300 per year drives the accelerating returns of the services-export circuit (+2.65) and stimulates domestic investment (+5.33).

A programmable e-hryvnia, integrated with tokenised recovery bonds in a hybrid decentralised finance to central bank digital currency architecture, forms our second proposal. The National Bank of Ukraine already counts programmed targeted money, virtual-asset circulation and cross-border payments among the use options shaping the e-hryvnia design [11]. Regulatory preconditions align with the digital euro preparation phase, during which the ECB finalises its rulebook in parallel with the legislative process [5, p. 2], and with MiCA [4]. Lower settlement costs are the purpose. Tokenised recovery bonds, embedded in the same ecosystem, build domestic demand for post-war recovery debt. This intervention also targets PC4, supporting a further +0.300 standard deviation increment.

Regulatory feasibility bounds how far either proposal can travel. MiCA sets a licensing and reserve regime for crypto-asset issuance and related services across the European Union [4], which any tokenised recovery bond marketed to European investors has to respect from the first issue onwards. The FATF's revised risk-based guidance imposes customer-identification and travel-rule duties on the providers that would operate a hybrid circuit [6, p. 107], and a design that ignored them would not survive correspondent-banking review, however elegant its cryptography. The OECD's Pillar Two model rules limit the tax preferences a jurisdiction may offer to internationally active groups [13, p. 8], so a special regime for service exporters has to compete on procedural quality and enforcement rather than on headline rates. Sequencing has a usable template: the ECB drafts its digital euro rulebook in parallel with the legislative process [5, p. 2], and the National Bank of Ukraine already lists programmed targeted money, virtual-asset circulation and cross-border payments among its design options [11].

The scenario simulation uses 6 000 draws. In the baseline inertial path, services exports reach 39.87 % of GDP by 2031, compared with 41.09 % under the component-based intervention scenario. These conditional estimates do not separately identify the effect of the proposed levy, e-hryvnia or tokenised recovery bonds.

Limitations of the estimates.

Our estimates carry limits that we state plainly. The services-export equation reaches an R-squared of 0.710, yet the adjusted value falls to 0.395, and that gap follows directly from fitting many parameters on a short

annual sample: 24 first differences for Ukraine, and 176 observations against 37 parameters per equation in the benchmark stage. A Theil coefficient of 0.536 places the model ahead of a naive no-change rule in sample, while the pseudo out-of-sample root mean square error of 4.910 stands well above the in-sample 2.505. The model is useful for reading the sign and the relative size of structural effects. It is not a forecasting instrument for point values, and the 2031 figures of 39.87 % and 41.09 % of GDP should be read as a scenario contrast rather than as a prediction.

Three further caveats bind the interpretation. The minimum per-indicator KMO of 0.273 means that several of the 32 effectors are weakly represented in the factor space, so component scores summarise the strongly loading indicators far better than the weak ones, and any policy reading of PC4 inherits that unevenness. Cluster structure is moderate rather than firm: a silhouette coefficient of 0.196, a cophenetic correlation of 0.735 and 56 % agreement with k-means together say that the benchmark grouping could shift under a different metric or linkage. The exchange-rate equation fails on both fit criteria, with an adjusted R-squared of -0.759 and a Theil coefficient of 0.818, and its flat path of 3.33 in both scenarios reflects that failure rather than any finding of exchange-rate neutrality.

Residual diagnostics are the one unambiguous success of the exercise. For the services-export equation the Ljung–Box p-value of 0.403, the Breusch–Pagan p-value of 0.074 and the Jarque–Bera p-value of 0.783 all exceed 0.05, so we detect neither residual autocorrelation nor heteroskedasticity, and normality is not rejected. That result supports the credibility of the posterior intervals we report, and it does nothing to relieve the sample-size constraint. Two conclusions are therefore unavailable from this design: we cannot claim a causal effect of either instrument on the export share, and we cannot extrapolate the accelerating PC4 return far beyond the range of modernisation observed in the benchmark episodes, because a quadratic term extended without bound predicts growth that no economy has delivered.

Conclusions. The results support examining digitally deliverable services as a potential channel of recovery, while the empirical equation measures aggregate services exports rather than the digital segment separately. The Ukrainian adjustment coefficient, estimated at $\lambda = -0.7476$, indicates faster estimated adjustment than in the benchmark. The positive quadratic coefficient of +1.5481 indicates curvature in the fitted relationship with modernisation, within the observed range.

The estimated external-resilience coefficient of -3.7427 indicates a conditional negative association in the services-export equation, not an independently identified effect of reserve or exchange-control policy. The proposed 3-5 % automatic levy on digital micro-exports and programmable e-hryvnia arrangements, potentially linked to tokenised recovery bonds, should therefore be treated as candidates for pilot evaluation. Their assumed connection to the annual PC4 increment of +0.300 standard deviations is a scenario interpretation, not an estimated instrument-specific transmission coefficient. The intervention scenario yields services exports of 41.09 % of GDP by 2031, but it does not establish that either proposal would deliver that outcome. The minimum per-indicator KMO of 0.273, adjusted R-squared of 0.395 compared with R-squared of 0.710, Theil coefficient of 0.536 and weak exchange-rate equation limit the findings. With 37 parameters per benchmark equation on 176 observations, implementation decisions require further validation, disaggregated data and direct assessment of administrative costs and exporter responses.

Further work should push in three directions. The first concerns data: series for services trade at a higher observation frequency would raise the count of observations relative to parameters and address the adjusted-R-squared gap that constrains us here, whereas our present design deliberately refuses temporal disaggregation of annual figures. The second is disaggregation by activity, since software development, business process outsourcing and digitally delivered professional services face different demand elasticities and different tax treatment, and a single services-export aggregate conceals that variation. The third concerns the institutional channel itself. We model the levy and the e-hryvnia through their effect on the modernisation component, whereas a pilot with settlement-level data could identify the elasticity of declared micro-exports to the collection mechanism directly, and it could test whether the accelerating return survives at higher levels of modernisation than the benchmark episodes contain.

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