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Yurii Khrushch
PhD Student,
Lesya Ukrainka Volyn National University
ORCID: https://orcid.org/0009-0003-1790-3855

Хрущ Ю.І.
Волинський національний університет імені Лесі Українки

SPEED OF ADJUSTMENT OF MACROECONOMIC CIRCUITS: UKRAINE AGAINST THE BENCHMARK CLUSTER

The article compares Ukraine's macroeconomic adjustment speeds with a benchmark cluster of historical recovery episodes. Six circuits are examined using nonlinear distributed-lag equations with error correction and Bayesian estimation. Benchmark posteriors inform the Ukrainian estimates. The largest coefficient difference concerns services exports, while inflation, investment and trade show smaller deviations. GDP growth displays oscillatory convergence under the model's adjustment interpretation. Weak fit limits the use of the exchange-rate equation. The contribution is a common empirical reference for interpreting national adjustment patterns. The comparison can inform recovery analysis, but does not establish the causes of coefficient differences or the effectiveness of specific policy instruments.

Key words: *macroeconomic adjustment, error-correction parameter, nonlinear distributed lag, NARDL, post-crisis recovery, economic stabilisation, services export, structural resilience.*

Formulation of the problem. Macroeconomic adjustment speed, captured by parameter λ, dictates recovery from exogenous shocks. It reveals systemic friction and structural flexibilities [1, p. 74]. For Ukraine's stabilisation [7], [15], evaluating these velocities is an urgent task. What we argue is that analysing adjustment speeds in isolation yields little value. Instead, a national parameter requires a historical benchmark. Diagnostic clarity reveals whether a circuit exhibits optimal flexibility or institutional rigidity. By estimating Ukraine's parameters against successful recoveries within a nonlinear specification, we can quantify divergence from optimal precedents. Targeted interventions follow [9, p. 15].

The policy stakes here are concrete. A circuit that absorbs half of its disequilibrium within a year needs a different instrument mix from one that absorbs a tenth, and a sequencing error wastes scarce fiscal room during reconstruction [15]. Donor programmes fix periodic review points [7], so the operative question is not whether convergence occurs in the limit but how much of the gap closes inside one review cycle.

Analysis of recent research and publications. The economic interpretation of adjustment speed remains a topic of active debate. M. Obstfeld and K. Rogoff documented the puzzle of excessively slow real exchange rate convergence, struggling to reconcile this empirical persistence with frictionless rational expectations [8, p. 203]. G. A. Calvo and M. Woodford subsequently attributed this delayed adjustment to staggered pricing, as nominal rigidities impede stabilisation [4, p. 383, 14, p. 139]. Overlapping contracts slow the whole adjustment process.

In our view, structural impediments matter just as much. O. Blanchard and L. H. Summers demonstrated that slow investment adjustment directly reflects physical and human capital hysteresis, which means that temporary shocks permanently degrade structural capacity [3, p. 27]. Expanding on these deep structural constraints, D. Acemoglu and J. A. Robinson showed that institutional rigidities further paralyse adaptive capacity [1, p. 84]. Relying on the advanced nonlinear autoregressive distributed lag (NARDL) approach, we calculate these asymmetric adjustment speeds [10, p. 624, 11, p. 281].

M. H. Pesaran, Y. Shin and R. P. Smith built the pooled mean group estimator precisely because adjustment speeds differ across units even where long-run relations do not, keeping short-run dynamics country-specific while the cointegrating vector is pooled [10, p. 621]. Y. Shin, B. Yu and M. Greenwood-Nimmo carried the logic into asymmetric cointegration, giving positive and negative partial sums of a regressor separate multipliers [11, p. 290]. Both treat the estimate as an object of inference about one economy, and neither offers a yardstick for reading its value. J. B. Taylor met the mirror problem on the policy side, calibrating his rule against observed central-bank conduct rather than an abstract optimum [12, p. 202].

Our benchmark rests on tools built for other questions. J. H. Ward minimises the within-group sum of squares at each merge, which suits recovery episodes because the natural

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number of groups is unknown beforehand [13, p. 241]. A. Gelman and D. B. Rubin supplied the variance ratio with which we certify that posterior draws are usable [6, p. 461]. Joining the two turns a set of historical episodes into a posterior, and a posterior can then serve as an informative prior for a second economy.

Institutional assessments of Ukraine state the same problem in narrative terms. The OECD survey records administrative measures in the currency market and their effect on price formation [9, p. 15]. IMF programme documents tie disbursement to quantitative benchmarks under periodic review [7], while the World Bank assessment prices the reconstruction gap those benchmarks are meant to close [15]. Work on central bank digital currency [2, p. 7] and the MiCA regulation [5] bounds the instruments we discuss below. What applied work lacks is a quantified reference that makes a national error-correction coefficient readable.

While calculated velocities properly guide monetary policy rules [12, p. 195], contemporary literature consistently interprets national λ coefficients in absolute isolation. Thus we propose a methodological improvement. Benchmarking an estimated error-correction coefficient against a posterior from comparable historical episodes improves diagnostic accuracy over interpreting it in isolation.

Formulation of the purpose of the article. The primary aim of this article is to estimate and comparatively analyse the speeds of macroeconomic adjustment across six essential circuits (inflation, real GDP growth, investment activity, goods and services trade balance, services export, and the exchange rate) for Ukraine against a benchmark cluster of successful post-crisis recoveries.

Presentation of the main research material. Using Ward's method [13, p. 236], we clustered 50 post-crisis episodes, and the benchmark comprises 11 successful recoveries, which feature mean inflation disbalance of 2.33 % and real growth averaging 5.78 %. To extract five effectors explaining 68.8 % of variance, we used principal component analysis. Effectors include monetary sovereignty, fiscal capacity, external resilience, structural modernisation, and institutional quality. Via a NARDL error-correction equation we model the macroeconomic circuits:

$$\Delta y_{i,t} = \alpha + \lambda \cdot \mathrm{ECT}_{i,t-1} + \sum_{j=1}^{5}\sum_{L=0}^{3}\left[\beta_{jL}\cdot \mathrm{PC}_{j,t-L} + \gamma_{jL}\cdot \mathrm{PC}_{j,t-L}^{2}\right] + \sum_{j=1}^{5}\left[\delta_j \cdot \ln(1+|\,\mathrm{PC}_{j,t}\,|) + \theta_j \cdot |\,\mathrm{PC}_{j,t}\,|^{\kappa}\right] + \varepsilon_{i,t}$$

Where λ denotes adjustment speed; $\mathrm{ECT}_{i,t-1}$ is the lagged error-correction term; κ = 2.5 is the power exponent; and $\varepsilon_{i,t}$ is the stochastic error. We estimated the specification via MCMC simulation [6, p. 457]. The benchmark's 240,000 posterior draws served as priors for Ukraine (1996–2023 data [16]), achieving large HPD narrowing. This is our core method.

Several choices at the benchmark stage deserve explicit statement. We standardised the nine disbalance indicators before clustering, since reserves in months of imports and inflation in per cent are not comparable in raw units, and we paired Ward linkage with the Euclidean metric. The silhouette coefficient rises from 0.134 at three groups to 0.196 at six and falls back to 0.192 at seven, so we retained six; that level is low, and we treat the partition as a working device rather than a discovered structure. Cophenetic correlation reaches 0.735, agreement with k-means only 56 %. On the 32 effectors of the 11 selected episodes the Kaiser criterion returned nine components, of which we kept five, explaining 68.8 % of variance, with Bartlett's test rejecting sphericity at χ^2 = 18 411.6 on 496 degrees of freedom.

Estimation detail matters for how λ should be read. Each benchmark equation carries 37 parameters on 176 observations, so we ran four chains of 90 000 iterations, discarded the first 30 000 of each as burn-in and retained 240 000 draws [6, p. 461]. Priors were Normal (0; 2.5) on structural coefficients and InvGamma (2; 1) on shock variance; acceptance rates stayed between 0.21 and 0.35, the maximum Gelman–Rubin statistic reached 1.016 and the smallest effective sample size 261. For Ukraine, 37 parameters on 24 first differences were impossible, so the specification keeps a constant, the error-correction term and the ten strongest regressors, at most 12 parameters, with the prior scale set to 2 between full transfer and an almost uninformative prior.

Parameter λ measures the proportion of macroeconomic disequilibrium corrected per period. A value of $-1<\lambda<0$ indicates monotonic convergence. If $\lambda<-1$, the path is oscillatory but convergent, given that the absolute value of one plus the coefficient stays below one.

Across inflation, investment, and trade, we find that Ukraine adjusts slightly faster than the historical benchmark, and prices and flows rapidly align with exogenous shocks.

The inflation circuit closes -0.8491 of its gap per year against the benchmark's -0.7949, and the mechanism behind the modest excess is compositional. Ukrainian consumer prices carry a high weight of tradables and of administratively reviewed tariffs, both of which reprice quickly once a shock lands, so staggered-contract rigidity has a narrower base here than in the economies that dominate the benchmark [4, p. 391]. Marginal returns agree: fiscal capacity lowers the log price index by 0.50 per unit while external resilience raises it by 0.52, so the circuit is pulled from two directions at once. Its adjusted R^2 of 0.121 is weak, and we claim no point forecasts from it.

Investment adjusts at −0.6466 against the benchmark's -0.5698, and the comparison carries more meaning than the small gap between them. Blanchard and Summers argued that capital and skills destroyed by a shock do not return with demand [3, p. 34], so an economy with a damaged capital stock ought to adjust slowly. That Ukraine does not adjust more slowly reflects a low base: gross capital formation starts far below the benchmark profile of 19.18 % of GDP, and any resumption of financing moves the ratio fast. Its constant of -2.4074 is significant, a

Table 1

Comparative analysis of the error-correction parameter (speed of adjustment)

Circuit	Benchmark λ	Ukraine λ	Ukraine 95 % HPD	Difference
Inflation (log CPI)	-0.7949	-0.8491	[-1.1914; -0.5082]	-0.0542
Real GDP growth, %	-1.2352	-1.2372	[-1.5524; -0.9189]	-0.0019
Investment, % of GDP	-0.5698	-0.6466	[-0.9068; -0.3832]	-0.0768
Trade balance, % of GDP	-0.4755	-0.5191	[-0.8254; -0.2223]	-0.0435
Services export, % GDP	-0.3374	-0.7476	[-1.1106; -0.3872]	-0.4102
Exchange rate (log)	-1.0180	-0.9481	[-1.3917; -0.5016]	+0.0700

standing drag the five components do not explain, while external resilience enters at -6.37, the largest negative entry in the return matrix: reserve accumulation and deficit compression crowd investment out.

The goods and services trade balance corrects -0.5191 per year, the slowest Ukrainian circuit in absolute terms. Physical rebalancing needs logistics, contracts and freight capacity, and none of those responds within a year. External resilience carries +7.85 per unit here yet enters the goods-trade equation at -4.5254 with z = 2.9, a sign pattern that separates the reserve-building channel from deficit compression and warns against treating the component as one lever. In-sample RMSE of 2.052 % of GDP sits against a pseudo out-of-sample RMSE of 21.748: the structural reading holds, the predictive use does not.

In extreme contrast to the benchmark's sluggish -0.3374, the empirically derived Ukrainian coefficient is -0.7476, which yields a services divergence of minus 0.4102. This developmental velocity is directly attributable to advanced digital services, featuring remarkably low physical capital intensity and large cross-border mobility. This lets us claim that the digital service sector operates on a separate macroeconomic timeline.

For the exchange-rate circuit we estimate visibly slower adjustment in Ukraine (-0.9481 versus the historical benchmark's -1.0180). This delayed structural correction (+0.0700) specifically reflects administrative friction deliberately introduced by fixed exchange-rate regimes, paralysing the underlying error-correction mechanism to preserve nominal stability at the expense of market adaptation. Rather than a defect, we read this negative narrowing as a diagnostic.

The real GDP growth circuit reliably demonstrates an adjustment parameter pushing beyond the traditional monotonic boundary of -1 (Ukraine: -1.2372). This accurately reflects an aggressive, structurally elastic rebound typical of post-shock recoveries, where deferred domestic consumption temporarily pushes measured output growth considerably beyond its sustainable steady state before settling into equilibrium.

Two coefficients sharpen these readings. Structural modernisation enters the services equation quadratically at +1.5481, so the return on digital capacity accelerates rather than accumulating in a straight line, while monetary sovereignty enters at −2.38: currency controls tax exactly the flows that adapt fastest. Institutional capital at lag two carries +5.7799 on output with z = 2.3, whereas monetary sovereignty at lag one shows -11.6040 and fails significance, so we attach policy weight to the first and none to the second.

Diagnostic tests confirm statistical integrity, since all Ljung–Box and Breusch–Pagan p-values exceed 0.05, and the investment circuit equation exhibits an excellent R-squared of 0.855, adjusted R-squared of 0.696, and Theil coefficient of 0.389, which means results stand firm. Regarding structural limitations we note the minimum per-indicator KMO statistic at 0.273.

Catastrophic collapse in statistical fit plagues the exchange-rate equation, and deliberate fixing of the hryvnia detached the currency from any fundamental macroeconomic effectors. Thus, the exchange-rate equation with an adjusted R squared of minus 0.759 and a Theil coefficient of 0.818 is indicative only.

Empirical speeds properly define stabilisation sequencing. Since interventions must target the highly responsive services export circuit (λ=-0.7476), we propose introducing programmable e-hryvnia architecture [2, p. 7] alongside a dedicated regulatory regime aligned with MiCA [5]. We also propose an automated levy on digital services micro-exports, which yields fiscal revenue but demands technical capacity that the tax authority does not yet hold.

Sequencing follows the measured speeds and component returns, not political convenience. The normalised aggregate return is highest for structural modernisation at +1.00 and negative for external resilience at -0.77, setting the annual increment at +0.300 standard deviations against -0.231. First stand the two instruments tied to modernisation: the levy on micro-exports of services collected by banks as tax agents, and tokenised recovery bonds on the e-hryvnia circuit. Second come institutional measures at +0.074, an institutional-oasis regime with arbitration under EU law and adoption of FATF and OECD Pillar Two rules. Third, at +0.051, sits netting of tax liabilities with digital VAT administration. The two-circuit currency regime, at −0.033, comes last.

Three constraints bound what these speeds can carry. The minimum per-indicator KMO of 0.273 means several effectors are weakly represented in the factor space, so a component score is not a clean measurement of the concept it names, and any circuit whose returns rest on those effectors inherits the weakness. With an adjusted R^2 of -0.759 and a Theil coefficient of 0.818, the exchange-rate equation sits below a naive no-change comparison; we report its λ of -0.9481 as

an ordering device only and draw no policy inference from it. The partition beneath the benchmark is weakly separated, at a silhouette of 0.196 and a cophenetic correlation of 0.735.

The remaining limits concern the data. Annual observations give 28 points for Ukraine and 24 first differences, which is why the transfer of benchmark posteriors was necessary and why it cannot be pushed further: at prior scale 2 the HPD interval narrows by 35.6 % for inflation and 12.5 % for investment, yet widens by 106.1 % for output, 40.2 % for services and 14.9 % for trade. A widening interval is not a defect of the method. It records real disagreement between the Ukrainian sample and the historical episodes, and tightening the prior would manufacture false precision. Intra-year timing stays untested, since no quarterly series entered the estimation.

Given exceptionally slow structural adjustment and severely negative adjusted fit, the exchange rate must be quarantined from structural targeting until market mechanics are restored. Stabilisation sequencing should therefore concentrate on the elastic trade and investment circuits, whose oscillatory horizons our estimates map directly.

Conclusions. The comparison with the benchmark cluster provides a common empirical reference for interpreting adjustment across Ukraine's macroeconomic circuits. Inflation, investment and the trade balance have moderately more negative error-correction coefficients than their benchmark counterparts. The largest difference concerns services exports: the Ukrainian estimate is -0.7476, compared with -0.3374 in the benchmark, giving a coefficient difference of -0.4102. This comparison identifies a distinctive adjustment pattern in aggregate services exports; it does not, by itself, isolate the contribution of digital activities or establish the cause of the difference.

The Ukrainian GDP-growth coefficient of -1.2372 is consistent with oscillatory convergence under the error-correction interpretation used in the article. The exchange-rate estimate must be treated more cautiously because the equation has weak diagnostic performance. It should not serve as a basis for structural policy targeting. Taken together, the estimates support a differentiated assessment of adjustment rather than a uniform recovery timetable. The proposed measures concerning services exports and institutional conditions remain policy hypotheses requiring separate assessment; the estimated speeds do not establish their effectiveness.

Further work should test the sensitivity of the comparison to alternative benchmark partitions, prior scales and data frequencies. Quarterly data could help distinguish within-year adjustment from patterns created by annual aggregation. Varying the prior scale would clarify how much each Ukrainian λ estimate depends on the domestic sample and how much on transferred information. A specification allowing different responses to widening and narrowing disequilibrium would extend the comparison. These checks are necessary before the estimated adjustment patterns can support more detailed operational recommendations.

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ШВИДКІСТЬ АДАПТАЦІЇ МАКРОЕКОНОМІЧНИХ КОНТУРІВ: УКРАЇНА ПРОТИ ЕТАЛОННОГО КЛАСТЕРА

Статтю присвячено порівняльному оцінюванню швидкості макроекономічної адаптації України та еталонного кластера історичних епізодів відновлення. Актуальність дослідження зумовлена потребою розрізняти темпи коригування дисбалансів у різних частинах економічної системи під час стабілізації та відбудови. Мета полягає у зіставленні параметрів корекції помилок за контурами інфляції, реального зростання ВВП, інвестицій, торговельного балансу, експорту послуг і валютного курсу. Методичний підхід поєднує формування історичної порівняльної групи методом Варда, аналіз головних компонент і байєсівське оцінювання нелінійних моделей із розподіленими лагами та механізмом корекції помилок. Апостеріорні розподіли, отримані для еталонного кластера, використано як інформативні апріорні розподіли в українських рівняннях. Науковий внесок полягає у використанні спільного емпіричного орієнтира для інтерпретації національних швидкостей адаптації замість їх ізольованого розгляду. Найбільша різниця між коефіцієнтами України та еталонної групи стосується експорту послуг: оцінки становлять відповідно -0,7476 та -0,3374. Інфляція, інвестиції й торговельний баланс характеризуються меншими відхиленнями від порівняльного профілю. Для реального зростання ВВП параметр -1,2372 відповідає осциляторній збіжності в межах застосованої інтерпретації коригувального механізму. Рівняння валютного курсу має низьку якість апроксимації, тому його оцінки не можуть бути самостійною підставою для структурного таргетування. Практичне значення дослідження полягає у підтримці диференційованого аналізу відновлення з урахуванням відмінностей між макроекономічними контурами. Водночас зіставлення коефіцієнтів не встановлює причин цих відмінностей, не виокремлює вплив цифрового сегмента послуг і не доводить ефективності конкретних податкових чи платіжних інструментів. Обмеження висновків пов'язані з короткими річними рядами, чутливістю до апріорних припущень,

слабким розділенням кластерів та неоднорідною якістю рівнянь. Подальші дослідження передбачають перевірку альтернативних порівняльних груп, масштабів апріорних розподілів і частоти спостережень для оцінювання стійкості виявлених закономірностей.

Ключові слова: *макроекономічна адаптація, параметр коригування помилок, нелінійний розподілений лаг, NARDL, посткризове відновлення, економічна стабілізація, експорт послуг, структурна стійкість.*

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