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Organizations, People and Sustainable Transformation in Times of Change

College of Economics
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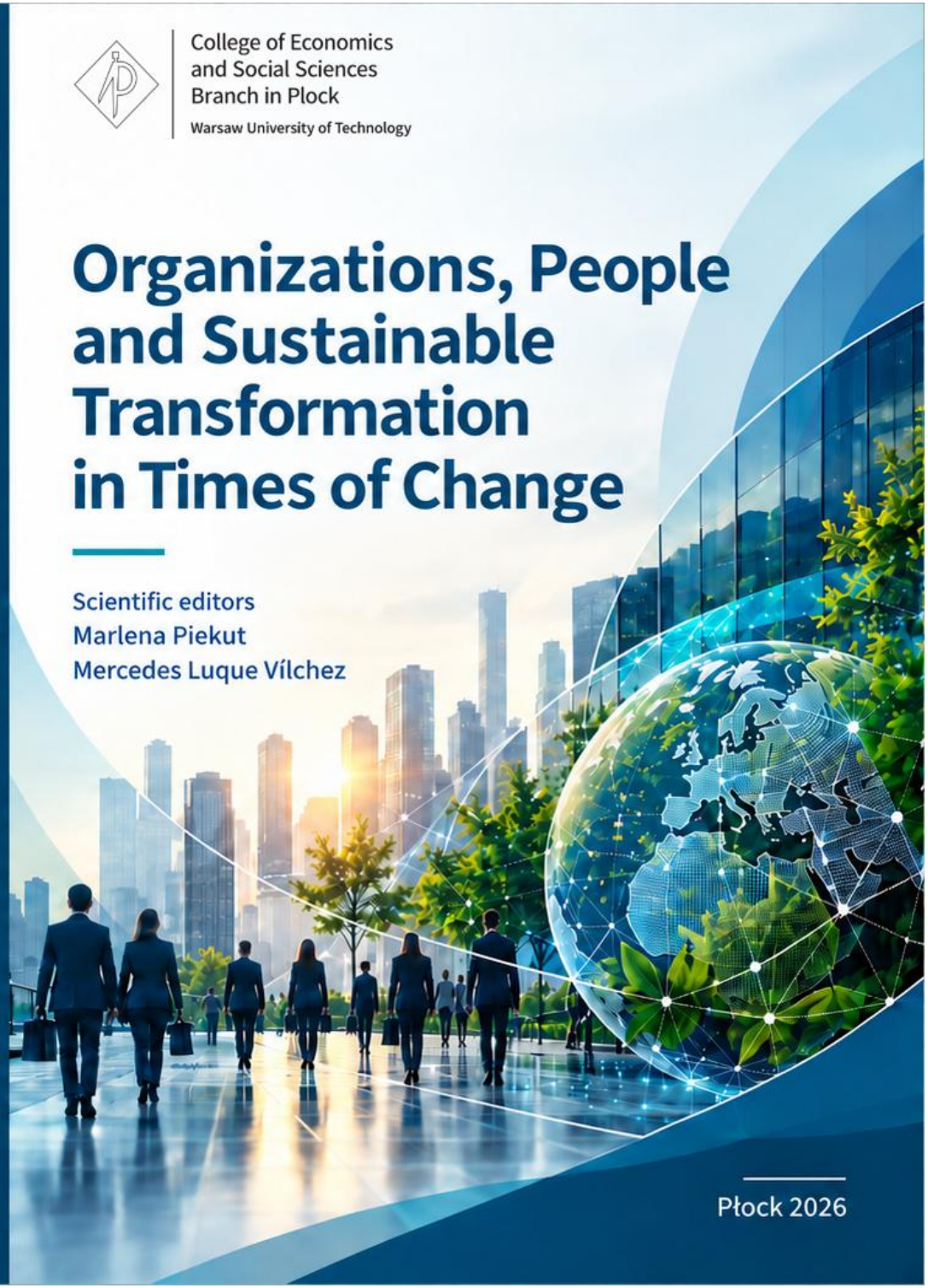
Branch in Plock
Warsaw University of Technology

Organizations, People and Sustainable Transformation in Times of Change

Scientific editors
Marlena Piekut
Mercedes Luque Vílchez



Płock 2026

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Introduction

Contemporary organizations, communities, and economic systems operate in an environment of profound and multidimensional change. Climate change, advancing digitalization, geopolitical instability, armed conflicts, and growing expectations regarding sustainable development are creating new challenges that require both theoretical reflection and practical solutions. The monograph *Organizations, People and Sustainable Transformation in Times of Change* responds to this context by addressing the question of how organizations and people can shape transformation processes in a sustainable, resilient, and responsible manner.

The title of the monograph reflects three interrelated perspectives. First, organizations, understood as economic, public, and social entities, face the need to redefine their strategies, business models, and management practices in response to uncertainty and environmental pressures. Second, people, including employees, households, local communities, and migrants, experience the consequences of these transformations in their everyday lives, in the labor market, in mobility, and in access to resources and services. Third, sustainable transformation is understood not merely as an adaptation to change, but as an active process of shaping development trajectories that reconcile economic objectives with the requirements of social justice and environmental protection.

The aim of the monograph is to present the diverse dimensions of these processes through interdisciplinary empirical and conceptual analyses. It brings together research in economics, management, sustainability studies, behavioral finance, and the social sciences. The authors address macroeconomic issues, such as economic growth, natural resources, and demographic and human capital losses; organizational issues, such as corporate strategy, governance, and risk management; and micro-social issues, including the organization of work within households, commuting safety, and housing conditions. They also consider sector-specific challenges related to energy, the circular economy, the automotive market, FinTech, healthcare, and digitalization.

The monograph is organized into three parts.

Part I – Economic, Environmental and Social Foundations of Sustainable Transformation – focuses on the fundamental determinants of transformation. It opens with an analysis of long-term development scenarios for Ukrainian

households under wartime and post-war conditions, based on the Solow growth model. The subsequent chapters examine the role of natural resource control in the socio-economic development of Sub-Saharan African countries, the relationship between social vulnerability and wildfire risk in Türkiye, and the potential for reusing medical equipment within the circular economy as a means of rebuilding Ukraine's healthcare system.

Part II – Organizations and Strategic Transformation – shifts the focus to the organizational level. It begins with the strategic dilemmas of the green transition in Chinese and Polish energy enterprises, followed by chapters on the formation of production strategies under the conditions of a circular economy and on strategic management in the transition to a regenerative economy. The part then turns to the behavioral determinants of market concentration and competition in the electric vehicle market in Türkiye, the use of FinTech innovations in proactive risk management in the context of EU integration, the adoption of artificial intelligence and digital technologies in the supply chains of European manufacturing companies, and the importance of process governance for the resilience of organizations in public healthcare.

Part III – People, Human Capital and Resilience in Times of Change – focuses on the human dimension of transformation. It includes studies on the organization of work in Slovak households, patterns of healthcare consumption among households with dependent children, and the relationship between the technical condition of dwellings and the energy cost burden of households in Poland. It also presents an analysis of the impact of digitalization on economic well-being through employment in the ICT sector and productivity, based on data from 23 European Union countries for the period 2017–2023. The part concludes with chapters on commuting safety as a new dimension of organizational responsibility toward employees, the economic consequences of brain drain from Ukraine during the war, and the potential application of behavioral finance tools to counter war fatigue.

The three parts should not be read as separate levels of analysis. Each of them combines perspectives: Part I places a household-level model alongside macroeconomic and sectoral studies, Part II links corporate strategies with market and governance issues, and Part III pairs household and workplace perspectives with cross-country and macro-level analyses of digital employment and human capital flight. The contribution of the volume lies precisely in these connections. Sustainable transformation is treated here as a

multilevel process in which macroeconomic conditions, such as growth, resource endowments, energy transition, and demographic change, shape organizational strategies and governance, and these in turn translate into the situation of households, employees, and communities. Several themes cut across the parts: the green transition and the circular economy, healthcare as a field of both organizational and social change, digitalization as both a driver of transformation and a source of new risks, and the consequences of the war in Ukraine. The last of these is examined at the level of households, infrastructure, human capital, and public attitudes, which illustrates the multidimensional consequences of the conflict. This distribution is not accidental; it reflects the conviction that sustainable transformation cannot be analyzed exclusively at a single level.

The monograph does not claim to provide an exhaustive account of the subject. Rather, its value lies in highlighting the complexity of transformation processes and in connecting organizational perspectives with human and environmental dimensions. The authors of the individual chapters employ diverse methodological approaches, ranging from macroeconomic modeling, panel data analysis, and empirical research to conceptual and behavioral approaches. Their common denominator, however, is the conviction that sustainable transformation requires the simultaneous consideration of institutional, organizational, social, and individual dimensions.

In presenting this monograph to its readers, we hope that the analyses brought together here will contribute to a deeper understanding of how organizations and communities can build resilience in times of uncertainty and will inspire further research into sustainable transformation.

Marlena Piekut
Mercedes Luque Vílchez

The authors of the individual chapters are solely responsible for the content of their contributions, including the accuracy of the data, the validity of the arguments, and the opinions expressed therein. The views presented in the chapters do not necessarily reflect those of the scientific editors or the publisher. The scientific editors accept no responsibility for the content of the individual chapters.

Editorial note. The chapters in this volume reflect the individual approaches of their authors. In accordance with the editorial policy adopted for this multi-author publication, the spelling conventions (British or American English), the notation of numerical data and mathematical symbols, and the formatting of tables, figures and bibliographies have been preserved as submitted by the authors and have not been fully harmonized across chapters.

PART I.

ECONOMIC, ENVIRONMENTAL AND SOCIAL FOUNDATIONS OF SUSTAINABLE TRANSFORMATION

Baldzhy M. (2026), Scenario-Based Application of the Solow Growth Model for Assessing the Long-Term Development of Ukrainian Households [in:] Piekut, M., & Luque Vílchez, M. (Eds.), Organizations, People and Sustainable Transformation in Times of Change, Kolegium Nauk Ekonomicznych i Społecznych, Politechnika Warszawska, Płock.

SCENARIO-BASED APPLICATION OF THE SOLOW GROWTH MODEL FOR ASSESSING THE LONG-TERM DEVELOPMENT OF UKRAINIAN HOUSEHOLDS

***Baldzhy Maryna*[1]**

Streszczenie

Artykuł przedstawia scenariuszowe zastosowanie modelu wzrostu Solowa do oceny długoterminowego rozwoju ukraińskich gospodarstw domowych w warunkach wojennych i powojennych. Celem jest adaptacja modelu Solowa do analizy wpływu zmian w oszczędnościach, dynamiki demograficznej, postępu technologicznego i deprecjacji kapitału na długoterminowe dochody gospodarstw domowych. Tematem jest długoterminowy rozwój ukraińskich gospodarstw domowych reprezentowany przez zagregowany model gospodarstwa domowego. Wyniki pokazują wrażliwość dochodów gospodarstw domowych na alternatywne parametry modelu i identyfikują potencjalne trajektorie powojennej odbudowy. Proponowane podejście rozszerza zastosowanie modelu Solowa na analizę scenariuszy na poziomie gospodarstwa domowego.

Słowa kluczowe: Model wzrostu Solowa; ukraińskie gospodarstwa domowe; analiza scenariuszy; rozwój długoterminowy; odbudowa powojenna; odporność gospodarstw domowych.

Summary

The article presents a scenario-based application of the Solow growth model to assess the long-term development of Ukrainian households under wartime and post-war conditions. The aim is to adapt the Solow model for analysing the effects of changes in savings, demographic dynamics, technological progress and capital depreciation on long-term household income. The subject is the long-term development of Ukrainian households represented by an aggregated household model. The results demonstrate the sensitivity of household income to alternative model parameters and identify potential trajectories of post-war recovery. The proposed approach extends the application of the Solow model to household-level scenario analysis.

Key words: Solow growth model; Ukrainian households; scenario analysis; long-term development; post-war recovery; household resilience.

JEL: D13, O11, O47, C63.

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Introduction

The prolonged military aggression against Ukraine has profoundly affected household economic development through population displacement, capital destruction, labour market disruptions, declining savings, and increased reliance on external assistance. These challenges highlight the need for analytical approaches capable of assessing alternative development pathways under conditions of uncertainty.

Although the Solow growth model is widely used to analyse long-term economic growth, its application to household development under wartime and post-war conditions remains limited. Existing studies rarely integrate demographic losses, capital destruction, and external support within a unified scenario-based framework.

This study addresses this gap by adapting the Solow growth model to evaluate the long-term development of Ukrainian households under alternative wartime and post-war scenarios. The proposed approach extends the traditional macroeconomic application of the model by providing a scenario-based framework for assessing household recovery trajectories and supporting evidence-based policy design.

1. Literature Review

The Solow growth model has long been recognised as one of the fundamental frameworks for analysing long-term economic growth, capital accumulation and income dynamics [Solow, 1956]. Subsequent studies expanded the model by incorporating demographic change, endogenous technological progress and alternative assumptions regarding capital formation [Scarpello & Ritelli, 2003; Ferrara, 2011; Cai, 2012]. More recently, the model has been adapted for scenario-based analysis and financial applications, demonstrating its flexibility in evaluating alternative development trajectories under different macroeconomic assumptions [Arias, 2010; Edeki et al., 2024]. However, these studies are primarily conducted at the macroeconomic level and provide limited insights into household development.

Households play a central role in economic growth through their decisions on consumption, savings and investment. Previous studies on Ukrainian households have focused mainly on financial behaviour, financial literacy and regional income differentiation [Shkvarchuk & Slav'yuk, 2019; Dudchyk et al., 2019; Makedon, 2020]. At the same time, international organisations emphasise that household resilience has become a key determinant of sustainable economic recovery, particularly under conditions of military conflict and prolonged uncertainty [World Bank, 2024; OECD, 2024; UNDP, 2023]. Recent research [OECD. Economic Surveys: Ukraine 2025; World Bank. Resilience, reliance, readjustment: How Ukrainians are coping with the war, 2024; World Bank. Updated Ukraine Recovery and Reconstruction Needs

Assessment, 2025; World Bank. Monitoring Living Conditions in Ukraine: 2024 Update, 2025] also highlights that war-induced shocks significantly affect household income, savings behaviour, labour participation and adaptive capacity, requiring analytical approaches capable of evaluating multiple recovery pathways rather than deterministic forecasts.

Scenario modelling has become an effective tool for analysing war-affected economies by evaluating alternative recovery pathways under different demographic, technological, and economic assumptions. Although the Solow model is widely used to explain long-term economic growth, its application to household development under wartime and post-war conditions remains limited. This study addresses this gap by adapting the model to assess long-term development scenarios for Ukrainian households.

2. Methods and Methodology

To analyze the functioning of Ukrainian households, analytical methods were employed. To address the identified research problem, modeling tools were applied– specifically, the methodology based on the Solow growth model was used to identify key factors affecting household functioning, with subsequent forecasts developed under different conditions specific to Ukraine.

In the classical Solow model, the long-term level of income per capita (or per household) is determined by the following key parameters: the savings rate (s), population growth rate (n), technological progress rate (g), depreciation rate (δ), and the production function parameter (e.g., the capital share (k) in income, denoted α in the Cobb–Douglas function). The derivative or elasticity of the steady-state income level (y*) with respect to these parameters reflects the income sensitivity. Ukrainian households, affected by war, inflation, external aid, and unstable migration, exhibit unique dynamics. To assess income sensitivity, data were collected on average household income, average savings rates, changes in the number of households/population, estimates of technological progress/labor productivity, and capital depreciation rates/asset devaluation. The selected data were incorporated into the Cobb–Douglas production function:

$$y = k^{\alpha}(A \cdot L)^{1-\alpha} \qquad (1)$$

y – household income; k – capital per household; A – level of technology; L – number of employed household members.

The steady-state income level is calculated as:

$$y* = \left(\frac{s}{n+g+\delta}\right) 1^{\frac{\alpha}{1-\alpha}} A, \qquad (2)$$

Sensitivity with respect to the savings rate is defined as:

$$\frac{\vartheta \ln y*}{\vartheta \ln s} = \frac{\alpha}{1-\alpha}. \qquad (3)$$

Sensitivity with respect to the population growth rate, technological progress, and depreciation rate is calculated as:

$$\frac{\vartheta \ln y*}{\vartheta \ln(n+g+\delta)} = \frac{\alpha}{1-\alpha}, \qquad (4)$$

here, α represents the capital share in income, indicating the portion of income generated by capital. Typically, α ≈ 0.3–0.4 for most economies (it may be higher or lower for Ukraine depending on the economic structure). A higher α implies stronger income sensitivity to changes in the savings rate or population growth–such an economy is capital-intensive. A lower α indicates a labor-intensive economy with lower income sensitivity to savings; (1–α) is the income share generated by labor.

Unlike conventional macroeconomic applications of the Solow model, the proposed framework considers the household sector as an aggregated representative household whose long-run income dynamics depend on capital accumulation, savings, demographic change and technological progress. Accordingly, the study does not attempt to forecast future economic performance but evaluates alternative development trajectories under explicitly defined assumptions.

The unit of analysis is the aggregated representative household of Ukraine. This approach enables the integration of macroeconomic growth theory with household income dynamics while maintaining consistency with the assumptions of the Solow model.

The analytical framework is based on the neoclassical Solow growth model, where output depends on physical capital, labour and exogenous technological progress. Household income is interpreted as a function of long-run equilibrium output generated under alternative combinations of model parameters. The steady-state solution serves as the basis for comparing the effects of different economic scenarios rather than estimating future values.

The research combines comparative analysis, economic modelling and scenario analysis. Scenario modelling is selected because the current wartime environment is characterised by high uncertainty, making deterministic forecasting inappropriate.

Model calibration is based on publicly available statistical information obtained from the State Statistics Service of Ukraine, the National Bank of Ukraine, the World Bank, the OECD and the United Nations World Population Prospects. These sources provide comparable indicators on household income, savings, demographic trends, macroeconomic performance and population dynamics.

The model parameters were calibrated using a combination of empirical evidence and theoretical assumptions commonly adopted in growth literature. The capital share parameter (α = 0.35) corresponds to the standard value widely applied in empirical Solow-type models. The savings rate (s = 0.15) reflects average household saving behaviour observed in Ukraine before and during the war. The depreciation rate (δ = 0.05) follows conventional assumptions adopted in macroeconomic growth models.

Technological progress (g = 0.015) represents a moderate long-term growth rate consistent with international empirical studies, while the population growth parameter (n = –0.01) reflects recent demographic decline associated with wartime migration and population losses. These values should be interpreted as calibration parameters for scenario analysis rather than precise empirical estimates.

Five alternative scenarios are constructed to evaluate household development under different economic conditions: (1) baseline development, (2) post-war recovery, (3) prolonged military shock, (4) accelerated technological recovery, and (5) humanitarian support scenario. Each scenario differs in the assumed values of savings, technological progress, depreciation and demographic dynamics while preserving the structural relationships of the Solow model. This design makes it possible to assess the sensitivity of long-run household income to changes in key economic parameters.

The study is fully reproducible because all model parameters, assumptions and data sources are explicitly reported. The analysis relies exclusively on publicly available statistical data and transparent calibration procedures.

Several limitations should be acknowledged. First, the model analyses an aggregated representative household and therefore does not capture heterogeneity across income groups or regions. Second, technological progress is treated as exogenous, consistent with the classical Solow framework. Third, the calibration relies partly on theoretical assumptions due to limited availability of wartime statistical data. Finally, the obtained results represent scenario-based assessments rather than empirical forecasts and should therefore be interpreted as potential long-term development pathways conditional on the adopted assumptions.

3. Results

Key household characteristics included savings, consumption, and capital accumulation. The household savings rate (s) was defined as the ratio of savings to income. The average marginal propensity to save (MPS) of Ukrainian households during 2001–2016 was negative (approximately –0.13), indicating that households financed consumption through debt and previously accumulated savings rather than current income. Such behaviour contradicts the Solow model assumption of a stable savings rate supporting capital accumulation [Shkvarchuk &Slav'yuk, 2019].

Household saving behaviour varied considerably across economic cycles. Before the 2014 crisis, MPS remained positive but declined over time, whereas in 2015 it reached –0.42 due to inflation, currency depreciation, declining confidence in the financial system, and rising living costs. Although savings partially recovered after 2017, they remained relatively low (about 8–12% of income). The sharpest deterioration occurred during 2014–2016, reflecting the economic consequences of Russian aggression and macroeconomic instability. In contrast, the exceptionally high

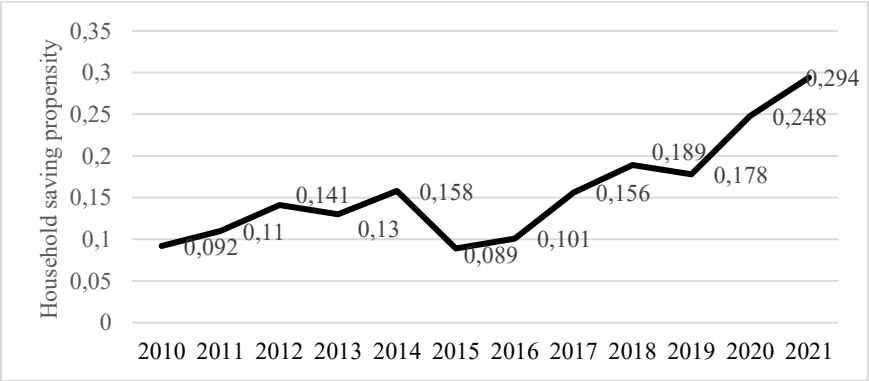
MPS recorded in 2020 (2,95) mainly reflected forced savings during COVID-19 lockdowns rather than a sustainable improvement in household financial capacity.

The second factor influencing household development is the consumption function. Household consumption in Ukraine is affected not only by disposable income but also by the exchange rate, current transfers, the discount rate, unemployment, and demographic changes [Makedon, 2020]. The analysis of 2009–2018 indicates that consumer behaviour increasingly reflected macroeconomic conditions rather than traditional income-based patterns.

Household saving propensity was directly related to disposable income and showed a gradual recovery after 2016. The highest value was recorded in 2021 (0,294), when households saved nearly 30% of their income, while the lowest (0,089) occurred in 2015 during the peak of the economic crisis. The sharp decline in savings was driven by the combined effects of military conflict, high inflation, currency depreciation, rising utility costs, and economic uncertainty, which shifted household priorities toward current consumption. These findings confirm that household saving and consumption behaviour in Ukraine is highly sensitive to macroeconomic shocks and should be considered when modelling long-term household development.

A critical factor in household decision-making is the propensity to save. The average savings propensity of Ukrainian households for 2010–2021 was calculated and found to be directly dependent on the amount of disposable income (Graph 1).

Graph 1. Savings propensity of Ukrainian households for 2010–2021



Source: calculated by the author based on statistical data [State Statistics Service of Ukraine, 2010-2021; National Bank of Ukraine, 2010-2021]

The third factor, capital intensity, indicates that capital depreciation limits the transformation of household savings into productive investment. As a result, obsolete capital constrains productivity growth despite increasing returns to capital [Krasnikova & Sugolov, 1999]. The adapted Solow model captures the relationship between savings, investment, capital accumulation, and productivity, demonstrating

that Ukrainian households are characterised by low savings, high sensitivity to macroeconomic shocks, and weak conversion of savings into productive capital.

The results of Solow model calculations for Ukrainian households in 2022 are presented in Table 1.

Table 1. Results of Solow model calculations for Ukrainian households

Indicator	Symbol	Result	Note
Capital share in income	α	0,35	Rebuilding Ukraine with the Private Sector, 2022
Savings rate	s	0,15	State Statistics Service of Ukraine
Population growth rate	n	-0,01	Population decline ≈-1% annually [World Population Prospects 2022 Summary of Results]
Rate of technological progress	g	0,015	Groningen Growth and Development Centre
Depreciation rate	δ	0,05	World Bank
Steady-state income level	y*	1,72	Calculated value (Formula 2)
Elasticity with respect to savings rate	–	0,538	Calculated value (Formula 3)
Elasticity to population, technology, and depreciation	–	-0,538	Calculated value (Formula 4)

Source: own study based on: [Solow, 1956; Edeki et al., 2024].

The baseline scenario serves as a benchmark for evaluating the long-term development of Ukrainian households within the adapted Solow growth model. Based on the selected parameters, the model estimates that steady-state household income is approximately 1.72 times the current average level. Assuming an annual household income of about UAH 420,000, the long-run equilibrium income would reach approximately UAH 722,400 (around EUR 17,200) per year, or UAH 60,200 (EUR 1,430) per month under stable post-war macroeconomic conditions.

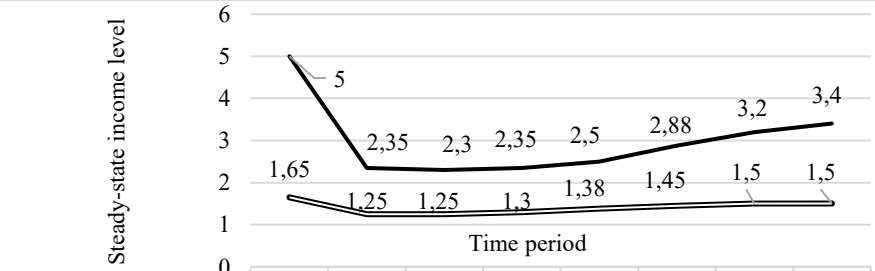
The scenario assumes a moderate household savings rate, gradual technological progress, negative demographic dynamics, and a constant depreciation rate. The results indicate that long-run household income depends primarily on capital accumulation and labour resources. While low savings and population decline

constrain investment and growth, technological progress partly offsets these effects by improving labour productivity and capital efficiency.

The second scenario evaluates the long-term effects of post-war recovery using the adapted Solow model. It assumes improved macroeconomic conditions driven by reconstruction, higher investment, labour market recovery, and technological modernisation. Specifically, the scenario increases the household savings rate to 0.20, assumes no further population decline (n = 0), accelerates technological progress to 3% per year (g = 0.03), and maintains the depreciation rate at 5% (δ = 0.05). Under these assumptions, the steady-state household income reaches approximately 1.637, corresponding to an estimated annual income of UAH 687,600 (about EUR 16,370). Although higher technological progress stimulates productivity, part of its positive effect is offset by the increase in the denominator of the Solow model (n+g+δ)(n + g + \delta)(n+g+δ). The results suggest that achieving higher long-run household income requires not only technological progress but also higher savings (e.g., s = 0.25) and more efficient capital utilisation through lower depreciation. As the analysis is scenario-based, the results should be interpreted as potential recovery pathways rather than deterministic forecasts.

Let us now explore several scenarios simulating different war durations in Ukraine using the Solow model. A war scenario is modeled with a military shock in year 10, representing a 50% capital loss (Graph 2).

Graph 2. War Scenario in the Solow Model Reflecting Realistic Household Dynamics



	1	10	12	15	20	30	40	50
Capital per capita	5	2,35	2,3	2,35	2,5	2,88	3,2	3,4
Per capita income	1,65	1,25	1,25	1,3	1,38	1,45	1,5	1,5

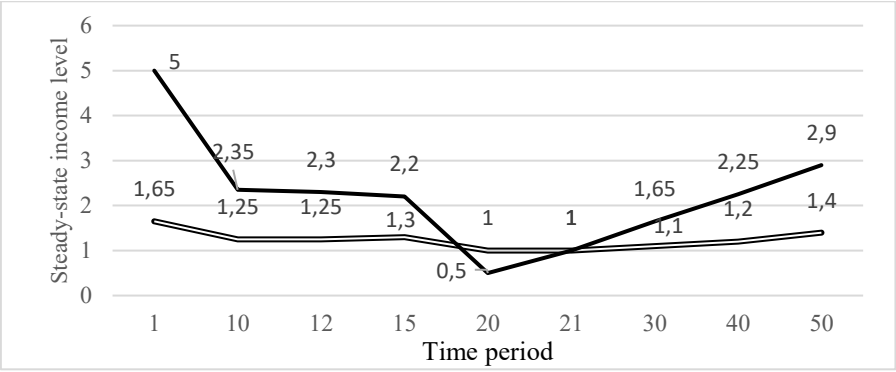
Source: Constructed by the author based on model calculations [World Bank, 2025; OECD. Economic Surveys: Ukraine 2025].

Following the sharp decline in capital, household savings (s) and technological progress (g) gradually recover over the subsequent decade. By approximately year 20, the economy returns to a positive growth path, although at a lower level than before the war shock. This scenario demonstrates that even a short but severe disruption may

have persistent long-term effects. The pace of recovery depends primarily on investment (s), technological progress (g), and demographic recovery (n).

The prolonged military shock scenario assesses the long-term effects of continued armed conflict on Ukrainian households, assuming lower savings, persistent capital destruction, demographic decline, weak investment, and slower technological progress. Compared with the baseline scenario, these factors substantially reduce steady-state household income by limiting capital accumulation and labour supply. Although technological progress partly mitigates these losses, it cannot fully compensate for declining investment and infrastructure destruction. The results highlight that sustainable recovery requires not only rebuilding physical capital but also policies that promote household savings, investment, technological modernisation, and labour market recovery. A deeper shock scenario, assuming 70% capital losses and a second wave of war, is presented in Graph 3.

Graph 3. War Scenario in the Solow Model with Two Military Waves (Years 10 and 20)



Source: Constructed by the author based on model calculations [World Bank, 2025; OECD. Economic Surveys: Ukraine 2025].

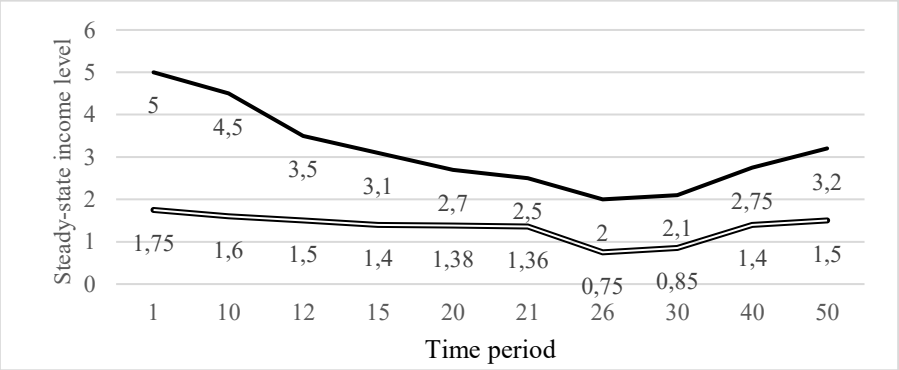
The graph illustrates two waves of military shocks. The first, occurring in year 10, causes a 50% capital loss, followed by a gradual recovery of savings (s) and technological progress (g) over the next decade. A second, more severe shock in year 20 results in a 70% capital loss, leading to a slower recovery and a deeper decline in household income. The findings demonstrate that repeated military shocks have persistent long-term effects on household development, highlighting the importance of not only capital restoration but also demographic recovery and behavioural adaptation for strengthening household resilience.

A simulation of the Solow model with dynamic parameters under wartime conditions, approximating real household behavior, is presented in Graph 4.

The graph in Graph 4 shows that capital and income decline after each wave of war (years 10 and 20), followed by gradual recovery. The dynamics are less optimistic than in the classical model: even during peaceful periods, the system does not return to high growth rates due to long-term war consequences (negative demographics, capital depreciation, loss of investment potential).

The results should therefore be interpreted as evidence of the sensitivity of household development to adverse structural conditions rather than as predictions of future economic outcomes. They illustrate how the accumulation of negative shocks may alter long-run equilibrium within the assumptions of the adapted Solow model.

Graph 4. The Solow model with dynamic household parameters under wartime conditions



Source: Constructed by the author based on model calculations [World Bank, 2025; OECD. Economic Surveys: Ukraine 2025].

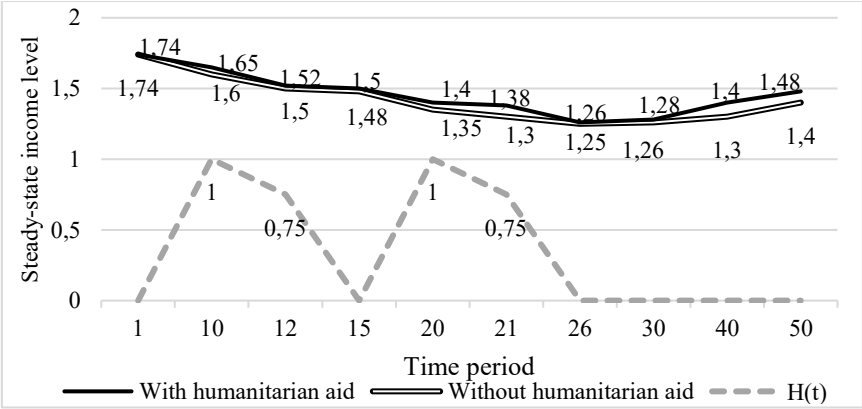
The accelerated technological recovery scenario evaluates the role of innovation and productivity growth in the long-term development of Ukrainian households during post-war reconstruction. It assumes faster technological progress driven by digital transformation, infrastructure modernisation, and human capital development while maintaining other model parameters unchanged.

The simulation shows that higher technological progress significantly increases steady-state household income by improving the productivity of both labour and capital. However, its positive effects are greatest when combined with higher household savings, investment, and demographic stabilisation. Technological progress alone cannot fully offset persistent population decline or insufficient capital accumulation.

These findings highlight the importance of integrating innovation, investment, and human capital policies into post-war recovery strategies. As the analysis is scenario-based, the results should be interpreted as potential development pathways rather than empirical forecasts.

The humanitarian support scenario evaluates the role of external financial assistance in strengthening the long-term resilience of Ukrainian households. Within the adapted Solow model, humanitarian aid is treated as an external factor that supports consumption, preserves household savings, and enhances future investment capacity rather than as a direct source of economic growth. By reducing the negative effects of wartime shocks, external assistance facilitates capital accumulation during the recovery period. To illustrate these effects, Graph 5 compares two scenarios: with and without humanitarian support.

Graph 5. The impact of humanitarian aid on household income in the Solow model



Source: Constructed by the author based on model calculations [World Bank, 2025; OECD. Economic Surveys: Ukraine 2025].

Without humanitarian support, household income declines sharply during the war shocks (years 10 and 20) and recovers only gradually. The inclusion of humanitarian aid reduces the depth of the downturn and accelerates recovery by supporting household consumption and preserving savings. Although aid does not directly increase capital, even moderate external assistance improves the long-term income trajectory (Graph 5).

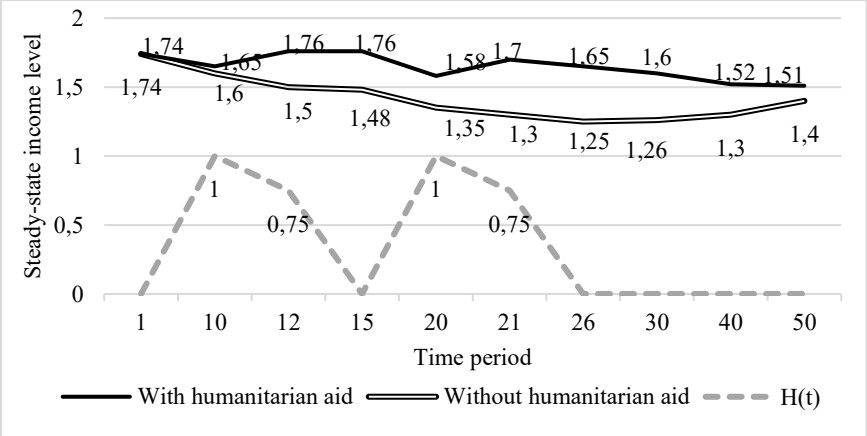
Graph 6 presents an alternative scenario in which external support is directed to capital investment rather than consumption. In this case, income recovers more rapidly because direct capital transfers immediately enhance productive capacity. Compared with humanitarian assistance, capital investment generates stronger and more persistent long-term effects, highlighting the importance of combining short-term social support with productive reconstruction measures.

The simulations show that humanitarian assistance mitigates the negative effects of prolonged military shocks by supporting household income and slowing the decline in long-term welfare. However, external aid alone cannot ensure sustainable economic

growth. Within the Solow framework, its long-term impact depends on its ability to complement capital accumulation, technological progress, and institutional recovery.

Support directed solely to current consumption provides short-term relief, whereas investment in employment, education, housing reconstruction, and small business development generates stronger and more persistent effects by enhancing household productive capacity. The greatest improvements are achieved when humanitarian assistance is combined with higher investment, technological progress, and demographic stabilisation. Therefore, humanitarian aid should be viewed as a complementary component of a comprehensive post-war recovery strategy rather than a substitute for structural economic reforms.

Graph 6. The impact of humanitarian aid as capital investment in the Solow model



Source: Constructed by the author based on model calculations [World Bank, 2025; OECD. Economic Surveys: Ukraine 2025].

The comparison of the five scenarios shows that long-term household development depends on the combined effects of savings, demographic dynamics, technological progress, and capital accumulation rather than on any single factor. The post-war recovery and accelerated technological recovery scenarios produce the most favourable outcomes, while the prolonged military shock scenario results in the lowest equilibrium income due to persistent capital losses and demographic decline. The humanitarian support scenario demonstrates that external assistance can reduce short-term losses but cannot substitute for sustainable economic growth.

The results identify technological progress as the strongest driver of long-term household development, although its benefits depend on adequate investment, household savings, and institutional stability. Moreover, simultaneous improvements in several parameters generate substantially greater long-run gains than isolated policy measures. As the analysis is scenario-based, the findings should be interpreted as

potential development pathways rather than empirical forecasts, providing a framework for evaluating alternative post-war recovery strategies.

The comparative assessment demonstrates that sustainable household development cannot be achieved through a single policy instrument. Instead, the model indicates that balanced improvements in savings behaviour, technological progress, demographic recovery and investment activity provide the most favourable conditions for strengthening household resilience and supporting long-term economic recovery.

Conclusion

This study developed a scenario-based adaptation of the Solow growth model to assess the long-term development of Ukrainian households under wartime and post-war conditions. Unlike traditional applications of the Solow model, which focus on macroeconomic growth, the proposed framework evaluates household development under alternative assumptions regarding savings, demographic dynamics, technological progress, capital depreciation, and humanitarian support.

The results show that household development is highly sensitive to capital accumulation, technological progress, and demographic change. Higher savings, investment, and productivity improve long-run equilibrium income, whereas prolonged military shocks, capital destruction, and population decline lead to less favourable outcomes. These findings confirm the importance of interactions among key growth determinants.

The main contribution of this study is the extension of the Solow model to scenario analysis of household development under armed conflict and post-war recovery. Rather than providing empirical forecasts, the model evaluates alternative development pathways based on explicitly defined assumptions and should therefore be interpreted as a scenario-analysis tool.

From a policy perspective, the results suggest that sustainable household recovery requires a coordinated combination of investment, technological modernisation, demographic stabilisation, and institutional reforms. Humanitarian assistance strengthens household resilience but is most effective when combined with broader recovery measures.

The study has several limitations. It is based on an aggregated representative household and calibrated using available statistical evidence and theoretical assumptions, reflecting the limited availability of wartime household data.

Future research should extend the framework by incorporating endogenous technological progress, household behavioural factors, regional heterogeneity, and micro-level data, as well as stochastic or agent-based modelling approaches to improve the assessment of uncertainty and long-term household resilience.

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NATURAL RESOURCE CONTROL AND IMPLICATIONS ON SUSTAINABLE SOCIO-ECONOMIC DEVELOPMENT OF SUB-SAHARAN AFRICAN COUNTRIES

Kassim Akanni[1], Fatai Sowunmi[2], Ndanusa Manzuma-Ndaaba[3]

Streszczenie

Kraje Afryki Subsaharyjskiej (SSA) są bogato wyposażone w zasoby naturalne, m.in. ropę naftową, gaz ziemny, diamenty, złoto, kobalt, miedź i rudę żelaza. Niniejsze badanie, oparte na analizie regresji wielokrotnej 21 zestawów danych dla ośmiu krajów SSA: Nigerii, Ghany, RPA, Kamerunu, Mozambiku, Tanzanii, Kenii i Demokratycznej Republiki Konga, wykazało, że jedynie Nigeria i Ghana uzyskują renty naftowe o pozytywnym i istotnym wpływie na wzrost społeczno-gospodarczy. W Nigerii, Demokratycznej Republice Konga i RPA istotny wpływ na ten wzrost miał również eksport rud i metali. W Tanzanii i Mozambiku istotne znaczenie miały PKB i stopa inflacji. Wyniki wskazują na potrzebę skuteczniejszego zarządzania zasobami naturalnymi oraz dywersyfikacji gospodarek SSA, tak aby dochody z zasobów były efektywnie inwestowane w poprawę jakości życia obywateli.
Słowa kluczowe: Zmienne makroekonomiczne; Zasoby naturalne; Rozwój społeczno-gospodarczy; Afryka subsaharyjska; Paradygmat zrównoważonego rozwoju.

Summary

The Sub-Saharan African (SSA) countries are richly endowed in natural resources such as crude oil, natural gas, diamonds, gold, coltan, cobalt, copper, and iron ore, among others. These resources should normally bring about significant socio-economic growth and improved quality of life of the citizenry. This study, using a multiple regression analysis of 21 data sets of eight SSA countries: Nigeria, Ghana, South Africa, Cameroon, Mozambique, Tanzania, Kenya, and DR Congo, found that only Nigeria and Ghana had oil rents, having a positive and significant effect on the socio-economic growth of their economies. For Nigeria, DR Congo, and South Africa, the export of ores and metals had a significant effect on socio-economic growth. The Gross Domestic Product and the rate of inflation had significant effects on the socio-economic growth of Tanzania and Mozambique. The study concluded that the SSA countries must embrace proper management of the natural resource endowments and strengthen the process of diversification of the economies to ensure that resource revenues are properly invested in other aspects of their national lives if they want to witness a positive transformation of the quality of life of their people.
Key words: Macroeconomic Variables; Natural Resource Endowments; Socio-economic Development; Sub-Saharan Africa; Sustainability paradigm;

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Introduction

Sub-Saharan African [SSA] countries are rich in natural resources, holding about 30% of the world's mineral reserves, 12% of its oil, and 8% of its natural gas [Bekalo et al 2010]. Major resources include crude oil, diamonds, gold, lithium, coltan, cobalt, copper, iron ore, and platinum, as well as vast agricultural land, timber, and significant untapped hydropower potential. Major natural resource endowments in this region include minerals such as gold in South Africa and Ghana, diamonds in Botswana, Angola, and Sierra Leone, cobalt and copper largely in the Democratic Republic of Congo and Zambia, while uranium is found in huge quantities in Niger and Namibia. Similarly, energy resources such as oil and natural gas are found in the Gulf of Guinea and Angola, while coal is abundant in South Africa and parts of Nigeria. Again, renewable energy resources such as hydropower are prominent in the DR Congo and Ethiopia. There are also agricultural and natural capital, including arable land for cultivating cash crops such as cotton, cocoa, coffee, cashew nuts, and shea butter. Forestry resources such as timber, fuelwood, and water are also in abundant supply in several places. Overall, these resources constitute a chunk of the merchandise exports of this region to other parts of the world, fetching a significant proportion of the Gross Domestic Product and foreign exchange to the producer countries. International research and development organisations have long recognised the complex and dynamic relationship between natural resources and economic development, and it attracts the attention of many scholars [Bekalo *et al* 2010; Ross 2002; Roy et al 2013; Sarraf and Moortaza, 2001] in development studies.

Expectedly, the abundance of natural resources in the Sub-Saharan African countries should bring about significant economic growth with an impactful and quality of life of the citizenry. However, research findings [Portugal 2016; Bekalo, *et al* 2010; Collier 2007] have indicated that many of these resource-rich countries still battle with socio-economic crises such as poverty, poor quality feeding, malnutrition among children, low- quality accommodation, sub-standard healthcare facilities, high child mortality rates, limited access to portable water, low rates of school enrolment, especially among primary and secondary school-age pupils, among others. Coupled with these, social vices such as armed robbery, money laundering, xenophobic attacks, cyber criminalities (such as internet frauds, bullying, and wire transfers), kidnapping, drug trafficking and violent acts (like terrorism and banditry) are commonplace occurrences in most of these. The following fundamental questions then arose;

i. Are the managers of the sub-Saharan countries able to fully deploy and control the available natural resources for the socio-economic growth of their regions?

ii. Do these natural resources significantly impact the standard of living/welfare status of the people of the region?

To address these questions, the following specific research objectives are stated:

i. To examine the trends in the use of natural resources for the macroeconomic benefits of the Sub-Saharan African countries

ii. To investigate the effect of the natural resource endowments/control on the standard of living/welfare status of the people in sub-Saharan African countries.

Relevant hypotheses were formulated to test the validity of the *a priori* expectations against the empirical findings of the study. It is hoped that the study's major findings will contribute to the existing body of knowledge on the impact of natural resource endowments on the socio-economic growth of SSA countries. The SSA countries are also expected to find the findings of this study useful as key pointers in their policy directions and implementations that can provoke a better synergy between macroeconomic indices and sustainable socio-economic growth in the region.

1. Literature Review

Natural resources are raw materials and components that are found within the environment and exist without human intervention or input. These resources are usually used to fulfil human needs, such as food, energy, and production. These materials include water, sunlight, air, land, minerals and wildlife. For instance, the Democratic Republic of Congo (DRC) produces more than 70% of the world's cobalt supply, South Africa holds the world's largest reserves of platinum group metals and significant gold deposits, Guinea is the global heavyweight in bauxite and aluminium production, while Nigeria and Angola dominate the sub-Saharan crude oil production and export

Expectedly, the presence of natural resources in any locality or country should be an asset for future socio-economic growth and sustainable development [Ola and Onyejiuwa [2023]. In other words, the richness of natural resources in a particular economy should increase its growth rate through export promotion and enhanced foreign exchange earnings. Unfortunately, however, the presence of these resources in many localities and countries has been a curse and recurring source of crisis, tragedy and disaster [Bekalo,*et al* 2010; Dramani et al 2022; Amare et al. 2024]. Examples of such ugly scenarios are found in the oil-rich Niger-Delta region of Nigeria, the Gulf region [in the Middle East], Mexico, and parts of Venezuela. These regions, despite the heavy presence of natural resource endowments, have failed to experience sustainable socio-economic growth. This observation therefore questions the notion [Sachs and Warner 1995] that there is a positive and significant correlation between the presence of natural resources in a particular region and the rate of socio-economic growth in such a region. In the same vein, Soros [2007], Stevens & Dietsche [2007] and Epo and Nochi-Faha [2020] argued that many natural resource-rich countries have continued to record low economic growth rates and indeed sometimes

are even more depressed than less endowed countries. It was added that this low socio-economic growth is often associated with the resource-rich countries' over-dependence on a particular resource while disregarding efforts at diversification and development of other industries. It was further noted that over-dependence on primary products could expose the resource-rich countries to the effects of external price shocks. Collier [2007], however, noted that the export of resources often causes resource-rich countries' currencies to increase in value in comparison to other nations' currencies, thus rendering these countries' other export activities rather uncompetitive in the international market. To further corroborate this position, the World Bank [2002], observed that in countries with large mining sectors (between 15 and 50% of exports), the GDP per capita dropped by an average of 1.1% a year, while in countries with very large mining sectors (over 50% of exports), the GDP per capita dropped by a remarkable 2.3% a year. Boschini *et al* [2012] and Moti [2019] further opined that natural resources do not harm economic growth but rather constitute a problem in the absence of quality and stable political institutions. These institutions, according to Roy *et al* [2013], normally comprise a varied range of indicators such as the enforcement of property rights, political (in) stability, regimes, social features (including differences in income and in ethnic, religious, and historical background) and social capital- the extent of civic activity and organisations. It was thus concluded that countries with lower-quality institutions were more likely to suffer a resource curse. In contrast, strong and effective institutions could offset some of the economic and social problems caused by resource dependence.

Ross [2002], however, observed that there is strong evidence that supports the notion that when a government gets more of its revenue from natural resources like oil, minerals, and timber, it is more likely to be corrupt because the total volume of resource revenues may not be effectively tracked and managed by government officials. In their own contribution, Grilli and Yang [1988],Ola and Onyejiuwa [2023] and Sini et al [2021] noted that countries that rely largely on natural resource endowments are often faced with the challenges of volatility of resource revenues since primary export prices tend to be unstable, compared to the global market prices of manufactured goods, especially in the last few decades.

In most SSA countries, natural resource endowments have not been properly and effectively managed by the government. Hence, there has not been a noticeable significant correlation between the presence of these resources and sustainable socio-economic growth rates in the region. Thus, Humphreys *et al* [2007] and Bekalo *et al*. [2010] noted that sustainable growth can be achieved by investing the rents from natural resources in other forms of wealth, which ultimately could translate into guaranteed positive values for the country's assets. This notion totally agrees with Humphreys *et al* [2007], who opined that consuming all revenues from natural resources without saving or investing parts of it will decrease the country's total

capital. It was therefore suggested that converting a chunk of natural resource stocks into financial assets and investing such assets in different forms could be a wise option.

2. Methodology

Area/scope of study

This study covers 8 selected sub-Saharan African (SSA) countries: Nigeria, Ghana, Tanzania, Kenya, the Democratic Republic of Congo, South Africa, Cameroon and Mozambique [Figure 1].

Source: See URL: https://www.britannica.com/place/sub-Saharan-Africa#/media/1/1013830/319041

The time series data were collected over 21 years, i.e., 2005-2025. These data cover specific socio-economic development indicators and some natural resource endowments of the SSA countries.

Hypothesis testing

To achieve the set objectives of the study, the following hypotheses, stated in the null forms, were used;

i. There is no positive and significant effect of the natural resource endowment on the socio- economic development of the Sub-Saharan African countries.

ii. There is no positive and significant effect of the natural resource endowment on trade volumes in Sub-Saharan African countries.

A two –tailed T-test statistic was used to test the validity of these two hypotheses. The t-statistics normally measure the difference between sample means and a hypothesised value relative to the data's variability. Thus, for a one-sample test, t-statistics,

$$t = \frac{\bar{x} - \mu}{s/\sqrt{n}}$$

where, $\bar{x}$=Sample mean; μ= Population mean ;s = Sample standard deviation, n=Sample size, while $s/\sqrt{n}$ = Standard error of the mean

Simply stated, the t-statistic is the ratio of the difference in a number's estimated value from its assumed value to its standard error. It is used in hypothesis testing via Student's t-test. The t-statistic was used to determine whether to support or reject the null hypothesis. In this study, 5% and 10% levels of significance were used.

Type of Data/Method of Data Collection

Time series data covering a period of 21 years [2005-2025] were used for this study. Information was gathered on the socio-economic development indicators and natural resource endowments of eight selected sub-Saharan African countries, including Nigeria, Ghana, Tanzania, Kenya, the Democratic Republic of Congo, Cameroon, South Africa, and Mozambique. The countries were purposively sampled from different geopolitical zones in Sub-Saharan Africa to ensure a broad geographic spread across the region. Borrowing from Sachs and Warner [1995], data were collected on the natural resources rents, which acted as a percentage of the GDP, and GDP per capita growth rate [%], ores and metals exports, which are a percentage of merchandise exports. Again, data were gathered on the annual rates of inflation,

lending interest rates [%], real interest rate (%), real effective exchange rate index [with 2010 as baseline], among others.

Method of Data Analysis

Multiple regression analysis was conducted [using the STATA package] for the eight countries' data using the GDP per capita growth rate (proxy for socio-economic development) of the selected SSA countries as the dependent variable. Independent variables are the Gross Domestic Product [GDP], oil rents, ores and metals exports, foreign direct investment [net inflows], annual inflation rates, lending rates, real interest rate, real effective exchange rate index and school enrolment [primary and secondary]. A simple linear regression exercise was repeated [by iteration] for each of the 8 SSA countries, one after the other.

Explicitly, the interaction between natural resource endowments and the socio-economic development of the SSA countries is expressed as follows:

$Y_i=\beta_0X_0+ \beta_1X_1+ \beta_2X_2+ \beta_3X_3+\ldots..+ \beta_9X_9+\varepsilon i$ …….. 1

Where,

Y_i= GDP per Capita growth rate [annual %]

β_0=Constant

β_1..... β_9 = Co-efficients of the parameters ($X_1 \ldots X_9$)

X_1= GDP [current, US Billion $]

X_2=Oil rents [% of GDP][a]

X_3=Ores and metals exports [% of merchandise exports]

X_4=Foreign Direct Investment, net inflows [% of GDP]

X_5=Inflation, Consumer prices [annual %]

X_6=Lending Interest rate [%]

X_7=Real Interest rate [%]

X_8=Real effective exchange rate index [with 2010=100, i.e. baseline]

X_9=School enrolment, primary and secondary [gross, gender parity index, GPI]

εi = Error Term[Stochastic in behaviour]

[a]= Natural resource rents are defined in this study as the difference obtained from the total revenue that can be generated from the extraction of the natural resource minus the cost of extracting these resources (plus normal return on investment reported by extractive enterprises). This is the sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents.

3. Results and Discussion

This section consists of the results and discussion of the study. Basically, the study examined the trends in the use of natural resources for the macroeconomic benefits of the Sub-Saharan African countries. It also investigated the effect of the natural resource endowments/control on the standard of living/welfare status of the people in

the region. The dependent variable in the regression model is the socio-economic growth rate, denoted as "growth," measured as the annual growth rate of real GDP per capita from 2005 to 2025. The independent variables in the model included the Gross Domestic Product [GDP], oil rents, ores and metals exports, foreign direct investment [net inflows], annual inflation rates, lending rates, real interest rate, real effective exchange rate index and school enrolment [primary and secondary]. The results of the simple linear regression analysis, which was selected because it provided the most desirable statistical values, using two-tailed test, indicated that out of the eight SSA countries, Nigeria, and Ghana had oil rents [% of GDP]-which is a proxy for natural resource endowment, having a positive and significant effect on the socio- economic growth of their countries [Tables 1 and 2]. Again, for Nigeria, ores and metals also had a significant effect on the socio-economic growth of the nation's economy at the 5% level.

Table 1: Nigeria -Result of Regression Analysis

Yi	Coeff.	Std.Err.	t-value	P>/t/	95% conf.	Interval
X_1	0.699	1.414	0.49	0.63	-2.42	3.81
X_2	0.395*	0.219	1.80	0.099	-0.08	0.87
X_3	4.219**	2.006	2.10	0.059	-0.19	8.64
X_4	0.993	1.434	0.69	0.503	-2.16	4.15
X_5	-0.110	0.129	-0.85	0.414	-0.39	0.17
X_6	1.086**	0.418	2.60	0.025	0.17	2.01
X_7	-0.032	0.076	-0.42	0.685	-0.20	0.14
X_8	-0.055	0.096	-0.57	0.580	-0.27	0.16
X_9	19.12	25.893	0.74	0.476	-37.87	76.11
Const.	-36.35	25.289	-1.44	0.178	-92.01	19.31

Number of observations=21;F(9,11)=4.26;Prob>F=0.0137;R-Squared=0.7769;Adj.R-Squared=0.5945;Root MSE=2.0337

Legend: *Significant at 10% level **Significant at 5% level

Table 2: Ghana -Result of Regression Analysis

Yi	Coeff.	Std.Err.	t-value	P>/t/	95% conf.	Interval
X_1	-0.109	1.485	-0.07	0.942	-3.378	3.158
X_2	1.184*	0.626	1.89	0.085	-0.194	2.563
X_3	0.355	0.733	0.49	0.637	-1.258	1.969
X_4	0.476	0.290	1.64	0.130	-0.163	1.114
X_5	-0.034	0.091	-0.38	0.712	-0.234	0.166
X_6	0.007	0.040	0.18	0.862	-0.083	0.096
X_7	0.017	0.122	0.14	0.894	-0.251	0.284
X_8	0.024	0.095	0.26	0.801	-0.184	0.233
X_9	-51.476	97.26	-0.53	0.607	-265.550	162.596
Const..	45.206	91.94	0.49	0.633	-157.184	247..598

Number of observations=21; F(9,11)=2.07;Prob>F=0.1267;R-Squared=0.6292;Adj.R-Squared=0.3258;Root MSE=2.3097

Legend: *Significant at 10% level **Significant at 5% level

This was captured by their t-values, measured at 5% and 10% levels of significance. For DR Congo, ores and metals exports [another proxy for natural resource endowment] and rate of inflation, which reflects consumer prices, had a significant effect on the socio-economic growth of the nation at 5 % and 10 % respectively
[Table 3].

Table 3: DR Congo -Result of Regression Analysis

Yi	Coeff.	Std.Err.	t-value	P>/t/	95% conf.	Interval
X_1	1.334	0.796	1.68	0.122	-0.418	3.087
X_2	0.197	0.389	0.51	0.623	-0.661	1.055
X_3	4.861**	2.049	2.37	0.037	0.350	9.372
X_4	0.365	0.291	1.25	0.236	-0.275	1.005
X_5	-0.296*	0.172	-1.727	0.112	-0.675	0.082
X_6	-0.080	0.057	-1.4	0.189	-0.206	0 .046
X_7	-0.004	0.059	-0.06	0.952	-0.136	0.128
X_8	-0.015	0.148	-0.10	0.923	-0.340	0.311
X_9	-5.831	18.695	-0.31	0.761	-46.98	35.32
Const..	-0.132	18.000	-0.01	0.994	-39.75	39.49

Number of observations=21; F(9,11)=;3.10; Prob>F= 0405;R-Squared= 0.7171;Adj.R-Squared= 0.4856;Root MSE=2.0688
Legend: *Significant at 10% level **Significant at 5% level

For Tanzania [Table 4], only the GDP had a significant but negative effect on the socio-economic growth of the nation's economy at the 10% level of significance, while all other independent variables had no significant effect.

Table 4: Tanzania -Result of Regression Analysis

Yi	Coeff.	Std.Err.	t-value	P>/t/	95% conf.	Interval
X_1	-0.0958*	0.054	-1.77	0.104	-0.215	0.023
X_2	-76.51	79.928	0.96	0.359	-252.43	99.41
X_3	0.063	0.086	0.74	0.478	-0.126	0.252
X_4	0.251	0.314	0.80	0.441	-0.440	0.941
X_5	-0.19	0.132	-0.14	0.890	-0.310	0.273
X_6	-0.039	0.911	-0.04	0.966	-2.045	1.965
X_7	0.12	0.202	0.58	0.573	-0.327	0.562
X_8	0.00	0.00	0.64	0.538	-0.002	0.004
X_9	205.83	192.76	1.07	0.308	-0.218.43	630.00
Const.	-198.19	178.86	-1.11	0.291	-591.86	195.494

Number of observations=21; F(9,11)=0.42;Prob>F=0.9004;R-Squared=0.2543;Adj.R-Squared=0.3559;Root MSE=2.3023
Legend: *Significant at 10% level **Significant at 5% level

For Mozambique, the GDP had a positive and significant effect on the nation's socio-economic growth, while the school enrolment, for both the primary and

secondary schools, had a significant but negative effect on the nation's economic growth profile [Table 5]. Both parameters were significant at the 5% level. All other macroeconomic variables have no significant effect on the socio-economic growth of Mozambique.

Table 5: Mozambique -Result of Regression Analysis

Yi	Coeff.	Std.Err.	t-value	P>/t/	95% conf.	Interval
X_1	1.126**	0.277	4.07	0.002	0.517	1.734
X_2	-4323	2.598	-1.68	0.124	-10.05	1.396
X_3	-0.006	0.0349	-0.17	0.865	-0.083	0.071
X_4	-0.036	0.052	-0.69	0.505	-0.151	0.079
X_5	0.161	0.221	1.34	0.208	-0.104	0.426
X_6	0.139	0.264	0.53	0.609	-0.442	0.720
X_7	-0.252	0.192	-1.31	0.216	-0.675	0.171
X_8	-0.006	0.038	-0.15	0.881	-0.089	0.077
X_9	-103.656**	21.529	-4.82	0.001	-0.151.02	-056.291
Const.	61.277**	15.819	5.14	0.000	46.460	116.094

Number of observations=21; F(9,11)=5.70;Prob>F=0.0044;R-Squared=0.8235;Adj.R-Squared=0.6792;Root MSE=1.5334

Legend: *Significant at 10% level **Significant at 5% level

In the case of South Africa, ores and metals exports and the net flow of foreign direct investments had significant effects on the nation's socio-economic growth at the 5% level, while the lending rate of interest was significantly impactful at the 10% level [Table 6].

Table 6: South Africa -Result of Regression Analysis

Yi	Coeff.	Std.Err.	t-value	P>/t/	95% conf.	Interval
X_1	1.525	1.03	1.48	0.168	-0.749	3.799
X_2	-0.317	1.73	-0.18	0.858	-4.129	3.495
X_3	-0.372**	0.10	-3.64	0.004	-0.596	-0.147
X_4	0.718**	0.21	3.47	0.005	0.262	1.173
X_5	-0.351	0.48	-0.74	0.477	-1.400	0.698
X_6	1.185*	0.59	2.01	0.069	-0.109	2.481
X_7	-0.445	0.48	-0.92	0.377	-1.509	0.629
X_8	0.095	0.07	1.33	0.222	-0.063	0.253
X_9	-2.572	21.02	-0.12	0.905	-48.831	43.688
Const.	-9.078	23.05	-0.39	0.701	-59.822	41.656

Number of observations=21; F(9,11)=7.19;Prob>F=0.0017;R-Squared=0.8547;Adj.R-Squared=0.7359;Root MSE=1.325

Legend: *Significant at 10% level **Significant at 5% level

However, contrary to expectations, this study indicated that despite the presence of huge deposits of natural resources [especially solid minerals like ores and metals, and crude oil], none of these natural resource endowments had significant effects on the socio-economic growth of Kenya [Table 7], and Cameroon [Table 8]. Thus, this finding instigates some questions on how these resources are being controlled and

managed, especially by government institutions, both in the upstream and downstream sectors. It also raises fundamental questions about the competence and levels of discipline among the managers of these resources. This agrees with the position of Roy et al [2013], which states that those countries with worse-quality institutions were more likely to suffer a resource curse, while strong and effective institutions should be able to offset some of the economic and social problems caused by resource dependence. Similarly, this finding corroborates the position of Amare et al [2024], which states that natural resource endowment is a curse with no or low-quality institutions and a blessing with high-quality institutions. Thus, building strong institutions and proper utilisation of natural resources help to minimise the adverse impact of resource endowments on economic growth.

Table 7: Kenya -Result of Regression Analysis

Yi	Coeff.	Std.Err.	t-value	P>/t/	95% conf.	Interval
X_1	0.066	0.232	0.29	0.779	-.0.443	0.577
X_2	68.237	125.877	0.54	0.599	-208.82	345.29
X_3	0.340	0.653	0.52	0.613	-1.097	1.78
X_4	1.172	1.379	0.85	0.414	-1.864	4.21
X_5	-0.175	0.141	-1.23	0..243	-0.487	0.137
X_6	-0.294	0.409	-0.72	0.485	-1.197	0.606
X_7	-0.446	0.525	-0.85	0.413	-1..600	0.708
X_8	0.054	0.053	1.02	0.329	-0.063	0.172
X_9	-96.639	86.872	-1.11	0.290	-287.8	94.56
Const..	97.702	80.395	1.22	0.250	-79.25	274.65

Number of observations=21; F(9,11)=3.57;Prob>F=0.0254;
RSquared=0.7450;Adj.RSquared=0.5363;Root MSE=1.1705
Legend: *Significant at 10% level **Significant at 5% level

Table 8: Cameroon-Results of Regression Analysis

Yi	Coeff.	Std.Err.	t-value	P>/t/	95% conf.	Interval
X_1	0.001	0.0588	0.02	0.983	-0.128	0.131
X_2	-0.056	0.490	-0.11	0.911	-1.135	1.02
X_3	-0.105	0.172	-0.60	0.558	-0.485	0.27
X_4	-0.103	0.647	-0.16	0.875	-1.528	1.32
X_5	-0.053	0.172	-0.11	0.763	-0.432	0.325
X_6	0.101	0.309	0.31	0.751	-0.579	0.780
X_7	0.347	1.222	0.28	0.782	-2.344	3.039
X_8	-0.052	0.132	-0.39	0.703	-0.343	0.239
X_9	3.491	60.260	0.06	0.955	-129.14	136.124
Const.	-3.038	61.619	-0.05	0.962	-138.66	32.587

Number of observations=21;
F(9,11)=1.07;Prob>F=0.4491;R-Squared=0.4672;Adj.R-Squared=0.0313;Root MSE=1.0854
Legend: *Significant at 10% level **Significant at 5% level

The generally high values for the Adjusted R^2-squared statistics again confirmed that the specified independent variables are largely responsible for the variations in the value of the dependent variable, i.e. the socio-economic growth rates [annual] of the SSA countries. For Tanzania and Kenya, the values of the Adjusted R^2-Squared, which stood at 0.2105 and 0.1196, respectively, indicated that the specified independent variables failed to account for most variations in the socio-economic growth rates in their economies.

Conclusion

This study examined the trends in the use of natural resources for the macroeconomic benefits of the Sub-Saharan African [SSA] countries. It also investigated the effect of the natural resource endowments on the socio-economic growth rates of the region. Oil rents [% of the GDP], ores and metals exports (% of merchandise exports), and other macroeconomic indicators such as the GDP, foreign direct investments (net inflows), rate of inflation, and lending rate were considered. Other selected macroeconomic variables included the real interest rate, real effective exchange rate index [with 2010 as the base year], and school enrolment –primary and secondary schools, which were captured and used for the study. Eight SSA countries, comprising Nigeria, Ghana, DR Congo, Tanzania, Kenya, Cameroon, South Africa, and Mozambique, were purposively selected due to their strategic positions in their regions. Data were obtained on their macroeconomic indices and their socio-economic growth rates between 2005 and 2025. Major findings are that out of the eight SSA countries, only Nigeria and Ghana had oil rents [% of GDP], which is a proxy for natural resource endowment, having a positive and significant effect on the socio-economic growth of their countries. Again, for Nigeria and South Africa, ores and metals exports (another proxy for natural resource endowment) had a significant effect on the socio-economic growth of their nations. However, contrary to the *a priori* expectations, for Ghana, Cameroon, Mozambique and others, the presence of ores and metals had no significant effect on the socio-economic growth of these countries.

This finding contradicts the earlier position, which was maintained by Ola and Onyejiuwa [2023], which indicated that there is no evidence of resource curse

found in SSA countries and suggested that resource-endowed SSA countries should discover profitable investments to reinvest proceeds from natural resources into other forms of renewable physical capital assets

Other independent variables, such as the GDP and rate of inflation, had significant effects on the socio-economic growth of Tanzania and Mozambique at 10% and 5 % levels, respectively. However, the lending interest rate had a positive and significant effect on Nigeria's and South Africa's socio-economic growth rates, while the rate of inflation and the school enrolment [primary and secondary] had a significant effect on

the socio-economic growth rates of DR Congo and Mozambique, respectively. Therefore, it may be recommended that Nigeria, Ghana, DR Congo, and South Africa should exercise more discipline, better management skills, and corruption–free approaches in the oil, ores and metals export sectors, if they must record sustainable socio-economic growth rates in their economies. These countries must also step up their efforts in the process of diversification of the economy by ensuring the resource revenues are carefully invested in other aspects of the economy, such as education, healthcare, agriculture, real estate and social infrastructures like roads, energy and transport services, among others. Both Nigeria and South Africa must reduce their lending rates to single digits to further enhance the pace of investment, increase the production of goods and services and expand job creation, while DR Congo must expand its market opportunities and embrace new production technologies to reduce the rate of inflation in their economy.

Again, the political and strategic public institutions must be strengthened and stabilised in the region to ensure continuity in management and sustainability in governance. With this done, the gross domestic product per capita growth rate, which ultimately translates to a better quality of living and general welfare of the citizenry, will improve in the Sub-Saharan African region.

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SOCIAL VULNERABILITY AND WILDFIRE RISK IN TÜRKIYE: A CONCEPTUAL PERSPECTIVE

Kıymet Yavuzaslan[2]

Streszczenie

Turcja doświadczała około 25 000–30 000 pożarów lasów w ciągu ostatniej dekady. Pomimo stosunkowo wysokiej częstotliwości pożarów, ich intensywność w ostatnich latach charakteryzuje się znaczną zmiennością. Badania nad odpornością klimatyczną coraz częściej podkreślają interakcję pomiędzy szokami środowiskowymi a strukturami społeczno-instytucjonalnymi; jednakże relacja między podatnością społeczną a dynamiką pożarów lasów pozostaje nadal niewystarczająco zbadana. Podczas gdy intensywność pożarów wykazuje silne wahania między poszczególnymi latami, wskaźniki społeczne, takie jak nierówności dochodowe i poziom dobrostanu społecznego, zmieniają się bardziej stopniowo i stabilnie. Rozbieżność ta sugeruje, że krótkookresowa dynamika pożarów jest przede wszystkim determinowana przez warunki klimatyczne, co pozostaje zgodne z dotychczasowymi badaniami nad reżimami pożarowymi. Jednocześnie utrzymywanie się strukturalnych podatności społecznych wskazuje, że czynniki te wpływają głównie na zdolność reagowania, procesy odbudowy oraz długoterminową odporność społeczną, a nie bezpośrednio na samo występowanie pożarów.
Słowa kluczowe: podatność społeczna, pożary lasów, odporność klimatyczna, adaptacyjne zarządzanie, Turcja

Summary

Türkiye experiences 25,000–30,000 fires over the past decade. Briefly to this relatively frequency, wildfire intensity is highly volatile in Türkiye recent years. Climate resilience research increasingly highlights the interaction between environmental shocks and socio-institutional structures; however, while prior research has either conceptualized vulnerability [Adger 2006] or operationalized it through composite indices [Cutter et al. 2003], the interaction between social vulnerability and wildfire dynamics remains underexplored. While wildfire intensity exhibits sharp inter-annual fluctuations, social indicators such as income inequality and happiness levels follow relatively gradual and stable trajectories. This divergence suggests that short-term wildfire dynamics are primarily driven by climatic conditions, consistent with existing research on fire regimes [Bowman et al. 2009]. However, the persistence of structural social vulnerabilities indicates that these factors are likely to influence response capacity, recovery processes, and long-term resilience rather than immediate fire occurrence.
Keywords: Social Vulnerability, Wildfires, Climate Resilience, Adaptive ManagmentTürkiye

JEL Codes: Q54; Q58; D63

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Introduction

Wildfires have become one of the most visible consequences of climate change across many parts of the world. Rising temperatures, prolonged droughts, declining humidity levels, and increasingly frequent heatwaves have intensified wildfire risks, particularly in Mediterranean climate regions. In recent years, Türkiye has experienced a significant escalation in wildfire activity, both in terms of frequency and spatial severity. The wildfire crises observed after 2021 revealed not only environmental vulnerabilities but also important socio-institutional challenges concerning preparedness, governance capacity, and community resilience.

Existing wildfire research primarily focuses on climatic drivers such as temperature anomalies, drought conditions, wind regimes, and vegetation characteristics [Bowman et al. 2009]. Although these environmental determinants remain essential for explaining wildfire occurrence and intensity, recent literature increasingly emphasizes that disaster outcomes are also shaped by underlying social and institutional structures. In this respect, resilience literature argues that climate-related disasters should not be evaluated solely as environmental phenomena but rather as multidimensional socio-ecological processes involving governance systems, economic inequality, institutional coordination, and adaptive capacity [Folke 2006; Adger 2006].

The concept of social vulnerability provides an important analytical framework for understanding these dynamics. Social vulnerability refers to the pre-existing social, economic, demographic, and institutional conditions that influence the ability of individuals and communities to anticipate, respond to, cope with, and recover from disasters [Cutter et al. 2003; UNDRR 2009a; UNDRR 2009b]. Communities characterized by inequality, limited institutional capacity, weak infrastructure, and low social cohesion often experience disproportionately severe disaster impacts even under similar environmental exposure conditions. This perspective is particularly important in the Turkish context. Türkiye experiences thousands of forest fires annually, while wildfire intensity has become increasingly volatile during recent years. At the same time, structural social indicators such as income inequality, regional disparities, governance capacity, and social resilience evolve more gradually over time. This temporal divergence suggests that while climatic conditions largely determine short-term wildfire dynamics, social vulnerability may significantly influence preparedness, response effectiveness, recovery capacity, and long-term resilience outcomes.

The wildfire crises experienced in Türkiye after 2021 further demonstrated the importance of socio-institutional factors in disaster governance. Public debates surrounding institutional coordination, emergency preparedness, local participation, and adaptive governance revealed that wildfire resilience extends beyond

environmental management alone. Consequently, understanding wildfire dynamics requires integrating climate change perspectives with broader discussions on governance quality, social vulnerability, and community resilience. The objective of this study is not to establish direct causality but to evaluate whether structural social vulnerabilities create conditions that weaken resilience and increase disaster sensitivity.

The paper contributes to the literature in three ways. First, it integrates wildfire dynamics with broader resilience and social vulnerability discussions. Second, it applies a socio-institutional perspective to the Turkish wildfire experience. Third, it demonstrates that climate resilience policies should combine environmental adaptation with governance reform and social inclusion.

1. Resilience and Social Vulnerability

The resilience perspective emerged from ecological research and later evolved into a broader framework for understanding social-ecological systems. Folke [2006] defines resilience as the capacity of a system to absorb disturbances while maintaining its core structures, functions, and adaptive capacities. In resilient systems, disturbances may generate opportunities for adaptation, learning, and institutional transformation rather than systemic collapse.

Resilience theory shifted environmental governance debates away from equilibrium-based approaches toward adaptive governance models that emphasize uncertainty, complexity, and transformation. According to Folke [2006], environmental systems are characterized by nonlinear interactions, thresholds, and dynamic feedback mechanisms. Consequently, effective governance requires flexibility, learning capacity, institutional coordination, and long-term adaptation strategies.

Cote and Nightingale [2012] criticize resilience approaches that overlook power relations, inequality, and social heterogeneity. They argue that resilience cannot be treated as a politically neutral concept because resilience for one group may simultaneously increase vulnerability for another. This perspective is especially relevant in wildfire contexts where unequal access to resources, infrastructure, and public services significantly affects adaptive capacity. Similarly, Duit et al. [2010] emphasize that governance systems increasingly face complex environmental challenges that require multilevel institutional coordination. Climate-related disasters such as wildfires expose weaknesses in fragmented governance structures and highlight the importance of adaptive governance.

The concept of social vulnerability provides an important theoretical bridge between environmental exposure and socio-institutional resilience. Social vulnerability refers to the pre-existing social, economic, demographic, political, and

institutional conditions that influence the capacity of individuals and communities to anticipate, cope with, resist, and recover from environmental hazards [UNDRR 2009b]. Unlike purely physical approaches to disaster risk, social vulnerability frameworks emphasize that disaster impacts are shaped not only by hazard intensity but also by inequalities embedded within social structures.

The vulnerability literature has evolved significantly since the 1970s. The concept of vulnerability was first systematically discussed in disaster studies by O'Keefe et al. [1976], while the use of the concepts "vulnerable" and "vulnerability" expanded substantially during the 1980s [Wisner and Luce 1993]. Because disaster studies developed as a multidisciplinary field, vulnerability has been conceptualized differently across disciplines [Ciurean et al. 2013]. Early technical approaches primarily focused on physical vulnerability and hazard exposure [UNDRO 1979], whereas later social science perspectives increasingly emphasized the economic, social, demographic, environmental, and institutional dimensions of vulnerability [UN/ISDR 2004]. From this point of view, vulnerability is now widely understood as a multidimensional and socially constructed process rather than a purely physical condition. UNDRR [2009b] defines vulnerability as "the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of a community to the impact of hazards." Social vulnerability, which constitutes the primary focus of this study, refers to the pre-existing structural conditions influencing the preparedness, response, coping, and recovery capacities of individuals, organizations, and communities facing external stressors [Roncancio and Nardocci 2016; Ge et al. 2013; Ge et al. 2019].

Previous studies demonstrate that social vulnerability is strongly associated with socio-economic status, demographic structure, inequality, spatial disparities, disability, social exclusion, and institutional capacity [Wisner et al. 2004; Cutter and Emrich 2006; Cutter and Finch 2008]. Although there is broad consensus regarding the main dimensions affecting social vulnerability, the specific indicators used to operationalize vulnerability continue to vary across temporal and spatial contexts [Cutter et al. 2003; Guo and Kapucu 2021]. This variability reflects the dynamic and context-dependent nature of social vulnerability within different socio-ecological systems.

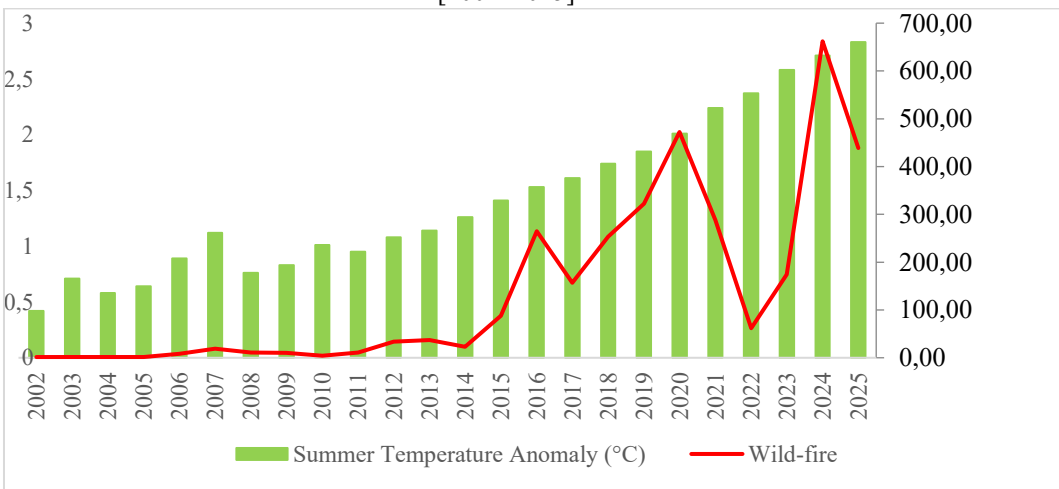
2. Wildfire Resilience in Türkiye and Social Vulnerability

Türkiye has experienced increasingly severe wildfire events during recent decades, particularly in Mediterranean and Aegean regions characterized by rising temperatures, prolonged drought conditions, and highly vulnerable forest ecosystems. Climate change, urban expansion, tourism-related pressures, and land-use transformation have collectively intensified wildfire susceptibility across the country.

Although Türkiye experiences thousands of forest fires annually, wildfire intensity and burned forest areas have become substantially more volatile during recent years. The wildfire in 2021 represented a critical turning point in Türkiye's environmental governance experience. Large-scale fires in Antalya and Muğla cities which are touristic centers exposed not only ecological fragility but also important socio-institutional vulnerabilities concerning emergency preparedness, institutional coordination, and adaptive governance capacity. These events demonstrated that wildfire disasters should not be interpreted solely as climatic phenomena but rather as multidimensional socio-ecological crises shaped by the interaction between environmental exposure and social vulnerability structures.

The Turkish wildfire experience illustrates an important asymmetry between environmental and social dynamics. While wildfire intensity fluctuates sharply depending on climatic conditions, social vulnerability indicators such as inequality, governance quality, and subjective well-being evolve more gradually. This suggests that climatic conditions trigger short-term wildfire events, whereas socio-institutional structures shape long-term resilience.

Graph 1. Wildfire Counts and Summer Temperature Anomalies in Türkiye [2002–2025]



Source: Republic of Türkiye Ministry of Environment, Urbanization and Climate Change 2025; JRC 2026

The Graph 1 presents the relationship between wildfire activity and summer temperature anomalies in Türkiye between 2002 and 2025. The data indicate a relatively continuous increase in temperature anomalies, particularly after 2015, reflecting the growing influence of climate-related warming across the country. Wildfire dynamics, however, follow a less stable pattern. Rather than increasing in a linear manner, wildfire intensity fluctuates sharply from year to year, suggesting that climatic warming alone cannot fully explain wildfire behaviour in Türkiye.

One of the most noticeable breaks appears during the post-pandemic period. Although summer temperatures continued to rise after 2020, wildfire activity displayed substantial volatility, culminating in the severe wildfire crisis of 2021. This divergence points to a broader reality frequently emphasized in resilience literature: environmental exposure may increase the probability of disasters, yet the scale of social and economic consequences depends heavily on institutional preparedness, governance quality, and adaptive capacity.

The graph therefore supports the main argument of this study. Wildfires in Türkiye should not be evaluated solely through climatic indicators such as temperature or drought conditions. Social vulnerability, institutional coordination, demographic pressure, infrastructure capacity, and human behaviour also shape how wildfire risks emerge and how societies respond under crisis conditions.

Climate change functions here as a long-term structural pressure increasing environmental fragility, especially in Mediterranean regions characterized by hotter and drier summers. Yet vulnerability itself develops more gradually. Inequality, regional disparities, governance limitations, and infrastructure deficiencies accumulate over time and often remain less visible until major environmental shocks expose them. For this reason, wildfire resilience cannot be reduced only to firefighting capacity or emergency response mechanisms. It also requires adaptive governance structures capable of combining environmental planning with long-term social resilience.

3. Determinants of Social Vulnerability in Türkiye

3.1. Governance Capacity and Institutional Coordination

The literature about the governance capacity with weak institutional coordination emphasizes that fragmented institutional structures weaken crisis management capacity and delay effective intervention [Duit et al. 2010]. Wildfire governance requires coordination among central government agencies, municipalities, emergency management institutions, local communities, and civil society organizations. The 2021 wildfire crisis in Türkiye generated intense public debates concerning institutional preparedness, coordination mechanisms, and emergency response capacity. Although emergency intervention capacity improved over time, the crisis exposed structural governance limitations including coordination problems, resource constraints, and communication challenges.

Resilience-oriented governance requires more than emergency intervention. It also involves prevention, long-term planning, risk communication, ecological monitoring, and public participation. Consequently, wildfire resilience should be treated as an integrated governance issue rather than solely an environmental problem.

3.2. Income Inequality and Regional Disparities

Economic inequality constitutes one of the most important structural determinants of social vulnerability and disaster resilience. Vulnerability literature consistently demonstrates that poverty, unemployment, unequal access to public services, and regional development disparities significantly reduce adaptive capacity during environmental crises [Adger and Kelly 1999; Cutter et al. 2003]. In unequal socio-economic structures, vulnerable populations often experience limited access to infrastructure, insurance mechanisms, healthcare services, transportation systems, and post-disaster recovery resources. Consequently, disaster impacts tend to be distributed unevenly across regions and social groups.

Recent evidence regarding Türkiye strongly supports this perspective. Yükseler and Tenikler [2026], in their entropy-based social vulnerability assessment conducted at the provincial level, identify demographic inequality, economic precarity, and adaptive capacity disparities as the principal drivers of disaster vulnerability in Türkiye. Their findings demonstrate that variables such as population density, unemployment, income inequality, family structure, and refugee concentration significantly increase social vulnerability across provinces.

The study further reveals that regional vulnerability levels differ substantially across Türkiye. According to their findings, Marmara, Mediterranean, and Southeastern Anatolia regions exhibit the highest social vulnerability levels due to rapid urbanization, population pressure, socio-economic inequality, migration intensity, and infrastructure stress. These findings are particularly important for wildfire resilience because Mediterranean regions simultaneously experience high climatic exposure and elevated socio-economic vulnerability.

Income inequality also weakens long-term adaptation capacity. Adger and Kelly [1999] argue that unequal access to economic resources limits the ability of communities to prepare for, cope with, and recover from environmental hazards. Similarly, Yohe and Tol [2002] emphasize that societies characterized by high inequality tend to experience greater vulnerability because resources necessary for adaptation are distributed unevenly. In the Turkish context, regional disparities between metropolitan centers, tourism-dependent coastal areas, and rural forest communities create differentiated resilience capacities during wildfire crises.

Migration pressure further intensifies these vulnerabilities. Yükseler and Tenikler [2026] identify the “Number of Syrians” variable as the single most influential social vulnerability indicator among 34 different variables included in their assessment model. The study emphasizes that rapid demographic transformation associated with forced migration increases pressure on housing systems, urban infrastructure, healthcare services, and local governance capacity. These pressures may reduce

institutional flexibility and emergency response effectiveness during climate-related disasters.

Wildfires also generate uneven economic impacts across sectors such as tourism, agriculture, forestry, and local services. Communities facing economic insecurity frequently prioritize short-term economic survival over long-term environmental adaptation investments. As a result, structural socio-economic inequalities may amplify disaster impacts and weaken resilience capacity over time.

3.3. Climate Change, Well-Being, and Environmental Governance for Community Participation

Climate-related disasters affect not only ecosystems and economies but also subjective well-being and social stability. The literature increasingly connects environmental sustainability with happiness, quality of life, and broader well-being indicators. In addition there is a huge literature highlights the importance of social capital in disaster resilience. Hofflinger et al. [2025] demonstrate that participation in social organizations and community networks significantly reduces wildfire vulnerability.

Social capital contributes to wildfire resilience in several ways:

- strengthening information-sharing mechanisms,
- facilitating collective action,
- increasing trust between institutions and citizens,
- supporting volunteer mobilization,
- accelerating recovery processes.

Rehdanz and Maddison [2005] argue that climatic conditions significantly influence subjective happiness through their effects on health, comfort, economic conditions, and environmental quality. Similarly, Laurent et al. [2024] criticize the overreliance on GDP as the sole measure of development and emphasize the importance of multidimensional well-being indicators.

Climate-related disasters such as wildfires generate psychological stress, uncertainty, displacement, and social disruption. Therefore, resilience policies should integrate mental health support, social cohesion strategies, and community-based recovery mechanisms.

Conclusion

Forest fires are no longer exceptional environmental events in Türkiye. They have become part of a broader climate reality that increasingly shapes ecological conditions, local economies, and public governance. What changed during recent years is not only the number of fires, but their scale, unpredictability, and destructive capacity. Particularly after 2020, hotter summers, prolonged droughts, and declining

humidity levels created conditions that made large-scale wildfire events far more difficult to control.

The previous wildfire cases in Türkiye, suggest that climate conditions alone do not fully explain wildfire dynamics. Temperature anomalies may increase fire susceptibility, yet the social consequences of wildfires vary considerably across regions and communities. Some areas recover relatively quickly, while others experience long-term economic disruption, institutional strain, and social fragmentation. This difference points directly to the role of social vulnerability.

One pattern repeatedly appears throughout the analysis. Wildfire indicators fluctuate sharply from year to year, whereas structural vulnerability indicators such as inequality, governance quality, demographic pressure, or regional disparities change much more slowly. Fires emerge suddenly. Vulnerability does not. It accumulates over time through institutional weaknesses, uneven development, infrastructure limitations, and social inequalities that remain largely invisible until a major crisis exposes them.

The wildfire crises after 2021 revealed several of these structural pressures simultaneously. Public discussions in Türkiye focused heavily on aircraft capacity and emergency response during the fires, but the deeper issue extended beyond technical intervention itself. Coordination problems, institutional fragmentation, communication failures, and uneven local preparedness became equally visible. In some regions, local solidarity networks and volunteer participation partially compensated for institutional limitations. In others, recovery proved far more difficult.

Another issue concerns the relationship between environmental governance and social resilience. Communities facing economic insecurity or infrastructure deficiencies often struggle to prioritize long-term adaptation. Migration pressure, regional inequality, and limited institutional capacity further complicate disaster preparedness, especially in highly exposed Mediterranean regions. In that sense, wildfire resilience becomes inseparable from broader questions of governance quality and social policy.

The discussion also points to the limits of reactive disaster management approaches. Wildfire resilience increasingly depends on long-term adaptation capacity rather than emergency intervention alone. In the Turkish context, this requires stronger institutional coordination, more inclusive governance structures, community-level participation mechanisms, and policies capable of reducing structural social vulnerabilities. Climate adaptation becomes far more effective when environmental planning is supported by social inclusion, public trust, and resilience-oriented governance practices. What emerges from the Turkish experience is a more layered understanding of wildfire resilience. Wildfires are clearly intensified by climate change, yet climate exposure interacts continuously with social and institutional structures. The problem is not simply ecological. It is also administrative, economic, and social.

This study brought together wildfire dynamics, resilience theory, and social vulnerability discussions within a common analytical framework. Rather than treating

wildfires only as environmental events, the paper approached them as multidimensional socio-ecological crises shaped by the interaction between climate pressures and structural vulnerability. Future studies may deepen this perspective through regional comparisons, longitudinal analyses, and empirical models examining how social vulnerability influences disaster resilience across different environmental conditions.

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MEDICAL EQUIPMENT REUSE IN THE CIRCULAR ECONOMY: OPPORTUNITIES FOR SUSTAINABLE HEALTHCARE RECOVERY IN UKRAINE

Nataliia Antoniuk[3]

Streszczenie

Niniejsze badanie analizuje potencjał ponownego użycia sprzętu medycznego w kontekście zrównoważonej odbudowy systemu opieki zdrowotnej na Ukrainie. Opierając się na przeglądzie literatury, dokumentów strategicznych oraz doświadczeń w zakresie odnawiania sprzętu, analiza wykazuje, że ponowne użycie może wzmocnić odporność opieki zdrowotnej poprzez poprawę dostępu do technologii, wydłużenie żywotności urządzeń, efektywniejsze wykorzystanie zasobów oraz redukcję odpadów. W ramach badania opracowano czterowymiarowy model koncepcyjny, który integruje aspekty ekonomiczne, środowiskowe, instytucjonalne oraz związane z ochroną zdrowia. Wykazano, że ponowne użycie sprzętu może uzupełniać nowe zakupy, służąc jako strategiczny mechanizm łączący zrównoważoną odbudowę sektora medycznego z przejściem na gospodarkę o obiegu zamkniętym.
Słowa kluczowe: gospodarka o obiegu zamkniętym; ponowne użycie sprzętu medycznego; odbudowa opieki zdrowotnej; odporność opieki zdrowotnej; zrównoważony rozwój; Ukraina.

Summary

This study explores the potential of medical equipment reuse for the sustainable recovery of Ukraine's healthcare system. Based on a review of literature, policy documents, and experience in equipment refurbishment, the analysis shows that reuse can strengthen healthcare resilience by improving access to technologies, extending equipment lifetimes, using resources more efficiently, and reducing waste. The study develops a four-dimensional conceptual framework integrating economic, environmental, healthcare, and institutional dimensions. It argues that reuse can complement new procurement, serving as a strategic mechanism linking sustainable healthcare reconstruction with the transition towards a circular economy.
Key words: circular economy; medical equipment reuse; healthcare recovery; healthcare resilience; sustainability; Ukraine.

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Introduction

The transition from a linear model of production and consumption towards a circular economy has become an important component of sustainable development policies. By promoting reuse, refurbishment, remanufacturing, and recycling, circular economy approaches seek to extend product lifetimes, retain material value, reduce waste, and improve resource efficiency. These principles are increasingly being applied to healthcare, where high consumption of materials, energy, pharmaceuticals, and medical technologies is accompanied by substantial volumes of medical and electronic waste. According to the World Health Organization [WHO 2025], the health sector contributes approximately 5% of global greenhouse gas emissions, highlighting the importance of improving resource efficiency and sustainability in healthcare.

Medical equipment is particularly relevant to this transition because its production requires substantial material and energy inputs, while some equipment may be replaced before the end of its functional lifetime. Reuse and refurbishment can therefore retain economic and functional value while reducing pressure on new procurement and waste generation [Karliner et al. 2019].

These approaches are especially relevant to Ukraine, where the full-scale Russian invasion has caused extensive damage to healthcare infrastructure and increased demand for medical services under severe financial and resource constraints.

Despite growing interest in circular healthcare, research has focused largely on environmental impacts, waste management, life-cycle assessment, and economic aspects. Comparatively less attention has been given to medical equipment reuse as a mechanism linking resource efficiency with healthcare recovery and resilience, particularly in post-war contexts. In Ukraine, this issue is of critical importance because reconstruction requires both rapid restoration of healthcare capacity and more efficient use of available resources.

The aim of this study is to explore the potential of medical equipment reuse as a circular economy strategy for supporting the sustainable recovery of Ukraine's healthcare system. The study examines international approaches to medical equipment reuse, considers their relevance to the Ukrainian context, and develops a conceptual framework linking reuse with sustainable healthcare recovery.

The research addresses the following question: How can medical equipment reuse contribute to circular economy implementation and sustainable healthcare recovery in Ukraine? The study is based on a critical review and synthesis of scientific literature, international policy documents, and analytical reports on circular healthcare, medical equipment management, and healthcare recovery.

1. Circular Economy and Medical Equipment Reuse

The application of circular economy principles has gradually expanded from manufacturing and waste management to resource-intensive sectors such as healthcare. This shift reflects growing recognition that healthcare sustainability requires more efficient management of materials, technologies, and infrastructure throughout their life cycles. Healthcare systems consume substantial quantities of energy, raw materials, pharmaceuticals, and medical technologies while generating significant volumes of medical and electronic waste. These characteristics make healthcare an important context for applying circular economy principles beyond conventional waste management. Consequently, the concept of circular healthcare has emerged as a framework that combines resource efficiency with the maintenance of high standards of patient care.

A growing body of literature suggests that circular healthcare extends beyond recycling. Higher levels of circular value may be achieved by preserving products and their functions through reuse, repair, refurbishment, remanufacturing, and life extension [Kirchherr, Reike and Hekkert 2017; Morseletto 2020]. This perspective challenges procurement models in which medical technologies may be replaced despite remaining technically functional. Instead, medical equipment can be considered a long-term healthcare asset whose functional value may be retained through appropriate maintenance and refurbishment. Recent evidence supports this perspective. Horn et al., examining magnetic resonance imaging (MRI) devices, found that strategies increasing the utilisation of existing equipment, particularly reuse, can provide substantial benefits in terms of climate impacts and critical raw material use [Horn et al. 2025].

Medical technologies are particularly relevant to circular approaches because their production involves substantial material and energy inputs and depends on complex supply chains and critical raw materials. Extending the operational life of existing equipment can therefore reduce the need for new production and associated resource consumption. The potential of life-extension strategies to retain material and economic value is similarly emphasised in recent environmental studies [Ellen MacArthur Foundation 2019] and [European Environment Agency 2022]. However, the environmental benefits of reuse are not automatic and depend on effective maintenance, technological upgrading, quality assurance, and the safe management of equipment throughout its extended life cycle.

Within this context, medical equipment reuse can include redistribution between healthcare institutions, refurbishment by qualified service providers, remanufacturing of high-value technologies, and donation programmes coordinated by public or humanitarian organisations. Although these approaches differ in implementation, they

share the objective of extending equipment life while maintaining technical, regulatory, and clinical safety requirements.

Empirical research provides further support for the relevance of life-extension strategies. Hoveling analysing approximately 1,400 medical devices available on the European market, found that reusable products represented nearly 95% of the identified circular design strategies [Hoveling et al. 2024]. This finding highlights the importance of retaining product functionality within circular approaches to medical technology. Horn provide more specific evidence from MRI devices, showing that increasing equipment utilisation through reuse can reduce environmental impacts and critical raw material demand compared with linear product systems [Horn et al. 2025]. Taken together, these studies suggest that preserving the functional value of existing medical technologies may provide environmental and economic benefits, although the magnitude of these benefits depends on the conditions under which equipment is maintained, refurbished, and returned to clinical use.

International practice also illustrates how refurbishment can be integrated into medical technology management. Programmes implemented by medical technology leaders include technical inspection, replacement of components, software upgrades, recalibration, and quality assurance before equipment is returned to clinical use [Philips Healthcare 2024; Siemens Healthineers 2024; GE HealthCare 2026]. These examples indicate that reuse can be supported by established technical and organisational processes. At the same time, they highlight the importance of specialised expertise, maintenance infrastructure, and regulatory capacity. Limited availability of competent technical personnel is identified as a potential constraint on the implementation of circular strategies for MRI devices [Horn et al. 2025]. Consequently, international models cannot simply be transferred to countries undergoing post-war reconstruction without considering differences in institutional and technical capacity.

Regulatory and organisational conditions are particularly important in healthcare because medical devices are subject to requirements concerning patient safety, traceability, performance reliability, cybersecurity, and post-market surveillance. MacNeill et al. identify fragmented maintenance documentation, limited availability of certified refurbishment services, and procurement systems favouring new equipment as factors constraining wider adoption of circular practices [MacNeill et al. 2020]. Horn et al. similarly indicate that existing legislation does not necessarily prevent circular solutions for MRI equipment but may provide limited incentives for their implementation [Horn et al. 2025]. The feasibility of reuse therefore depends not only on the technical condition of equipment but also on certification procedures, regulatory clarity, institutional coordination, and stakeholder acceptance.

Overall, the literature indicates that medical equipment reuse can be understood as an important component of circular healthcare rather than simply a waste-reduction

measure. Its potential contribution encompasses resource efficiency, retention of economic and functional value, access to medical technologies, and healthcare resilience. These characteristics make reuse particularly relevant to countries facing resource constraints and large-scale reconstruction challenges. For Ukraine, this perspective provides a basis for considering medical equipment reuse not only as a circular economy practice but also as a potential component of sustainable healthcare recovery.

2. Medical Equipment Reuse for Sustainable Healthcare Recovery in Ukraine

The full-scale Russian invasion has fundamentally transformed the priorities of Ukraine's healthcare system. The recovery challenge extends beyond restoring damaged hospitals and replacing destroyed infrastructure. It involves rebuilding healthcare capacity under conditions of continuing resource constraints, disrupted supply chains, uneven access to services, and substantial demand for modern medical technologies. According to the World Health Organization [WHO 2023; WHO 2024], repeated attacks on healthcare facilities have disrupted medical services and reduced healthcare capacity. In this context, reconstruction also creates an opportunity to reconsider how existing healthcare resources can be mobilised and managed over the longer term.

For Ukraine, the relevance of medical equipment reuse arises from the combination of infrastructure losses, limited financial resources, and continuing demand for diagnostic and therapeutic technologies. Equipment that remains technically functional but is underused or no longer required because of organisational changes may represent an underutilised resource within the healthcare system. Its assessment, refurbishment, redistribution, or transfer to facilities with unmet needs could therefore complement conventional procurement and humanitarian assistance. Recent evidence from a French university hospital further indicates that the adoption of refurbished medical imaging equipment depends strongly on technical reliability, long-term performance, and access to updated functionalities, while environmental and cost considerations play a secondary role in users' decisions [Calixto et al. 2026]. This highlights the importance of ensuring technical and clinical reliability when considering reuse in healthcare recovery.

The Ukrainian context presents several specific constraints. Healthcare facilities have been damaged or destroyed, medical services have been reorganised in response to population displacement and changing needs, and public resources remain under considerable pressure. At the same time, reconstruction programmes must address urgent technological needs while maintaining transparency and efficiency in public expenditure. Under these conditions, functional equipment located outside facilities

with current unmet needs may represent an important but insufficiently recognised resource. Developing mechanisms for identifying, assessing, documenting, and reallocating such equipment could help connect existing resources with areas of unmet demand.

Ukrainian academic research has addressed multiple dimensions of healthcare transformation, including healthcare reform, financing, hospital management, decentralisation, digitalisation, public procurement, medical waste management, and post-war reconstruction [Antoniuk, Bochko and Kulczycka 2024; Brukhno et al. 2025; Ministry of Health of Ukraine 2024]. Research has also highlighted challenges related to the efficiency of medical equipment procurement, the quality and appropriateness of purchased technologies, and the need to improve procurement mechanisms under wartime conditions [Khmurova and Volkova 2023; Stepanenko, Lekhan and Slabkiy 2023]. However, comparatively limited attention has been given to the systematic reuse, refurbishment, and redistribution of existing medical equipment as components of healthcare recovery. Research on medical waste has similarly focused primarily on waste treatment, recycling, and regulatory compliance. Consequently, how the functional value of existing medical technologies can be retained and redistributed within the healthcare system remains comparatively underexplored.

Addressing this gap requires more than the availability of reusable equipment. It requires cooperation among healthcare institutions, public authorities, technical service providers, manufacturers, and humanitarian organisations, together with clear procedures for technical assessment, maintenance, certification, traceability, and safe redeployment. International experience provides useful reference points, but these mechanisms need to be considered in relation to Ukraine's institutional capacity and evolving regulatory environment rather than transferred without adaptation.

Medical equipment reuse should therefore be considered a complementary element of Ukraine's healthcare recovery strategy rather than a substitute for new investment. New equipment remains essential where existing technologies are obsolete, unsafe, or unable to meet clinical requirements. Where functional equipment can be safely maintained, refurbished, and redeployed, however, continued use may reduce pressure on reconstruction budgets while supporting the restoration of healthcare capacity. The potential contribution of such an approach can be considered across three closely connected objectives: faster restoration of healthcare capacity, more efficient use of constrained financial and material resources, and greater long-term resilience of the healthcare system.

These considerations provide the basis for the conceptual framework developed in the following section, which examines medical equipment reuse through economic, environmental, healthcare, and institutional dimensions, while treating technical and regulatory capacity as cross-cutting conditions for implementation.

3. A Strategic Framework for Circular Healthcare Recovery in Ukraine

The review of international experience and Ukraine's healthcare recovery challenges indicates that medical equipment reuse can be considered a strategic component of healthcare reconstruction rather than merely an operational or waste-management activity. Unlike conventional procurement models, which rely primarily on the acquisition of newly manufactured technologies, circular approaches seek to retain the functional value of existing equipment through assessment, maintenance, refurbishment, redistribution, and controlled life extension. In the context of post-war recovery, this approach may complement new procurement by creating an additional pathway for restoring healthcare capacity while supporting more efficient use of financial and material resources.

For Ukraine, the relevance of reuse is linked not only to the need for cost efficiency but also to the challenge of restoring healthcare services under conditions of uneven infrastructure recovery and changing patterns of demand. Technically functional equipment may remain underused or unevenly distributed because of organisational changes, population displacement, or differences in local healthcare needs. Where such equipment can meet current clinical and safety requirements, its identification and redeployment may complement conventional procurement and humanitarian assistance.

The potential contribution of reuse, however, depends on more than the physical availability of previously used equipment. Equipment can only be returned to clinical use when appropriate technical, regulatory, and organisational conditions are in place. These include technical assessment, evaluation of remaining useful life, maintenance or refurbishment where necessary, certification, traceability, and monitoring after redeployment. Evidence on refurbished medical imaging equipment indicates that technical reliability and long-term performance are important conditions for user acceptance [Calixto et al. 2026]. More broadly, the analysis presented in this study suggests that circular healthcare requires the coordination of technical, regulatory, operational, and stakeholder capacities rather than isolated reuse initiatives. This does not imply that reuse should replace conventional procurement. Rather, it introduces a broader lifecycle perspective into decisions concerning how healthcare technologies are acquired, managed, and retained within the system.

The implementation of such an approach also requires coordination among multiple actors. Healthcare institutions can identify available equipment and unmet needs; technical service providers can assess, maintain, and refurbish equipment; public authorities can establish regulatory and procurement conditions; manufacturers may contribute technical knowledge and access to spare parts; and humanitarian organisations can support redistribution. The main challenge is therefore not only the

availability of reusable equipment but also the institutional capacity to organise these activities within a coherent and accountable system.

Based on the reviewed literature, international experience, and the analysis of Ukraine's healthcare recovery needs, the principal opportunities, barriers, and corresponding policy implications of medical equipment reuse are summarised in Table 1.

Table 1. Opportunities and barriers to medical equipment reuse for sustainable healthcare recovery in Ukraine

Dimension	**Opportunities**	**Challenges**	**Policy implications**
Environmental	Reduced medical and electronic waste; lower demand for virgin raw materials; reduced greenhouse gas emissions	Limited infrastructure for equipment recovery and end-of-life management	Development of a national circular healthcare strategy
Economic	Lower procurement costs; prolonged equipment life; more efficient allocation of healthcare budgets	Limited financing of refurbishment facilities	Introduction of circular public procurement and financial incentives
Healthcare	Faster restoration of hospitals; improved access to diagnostic technologies; increased system resilience	Certification and quality assurance requirements	National standards for refurbished medical equipment
Institutional	Enhanced cooperation among hospitals, donors and humanitarian organisations	Fragmented legislation and institutional coordination	Harmonisation with European Union medical device regulations

Source: developed by the author based on the reviewed literature

The comparative assessment presented in Table 1. indicates that the potential contribution of reuse is multidimensional. The proposed framework therefore considers four interrelated dimensions: economic, environmental, healthcare, and institutional. The economic dimension concerns the potential for more efficient allocation of constrained financial resources and the retention of value embedded in existing equipment. The environmental dimension relates to the extension of equipment lifetimes and the potential reduction of demand for newly manufactured technologies and associated material inputs. These potential benefits, however, are conditional on whether reuse remains technically feasible and economically justified.

The healthcare dimension focuses on the contribution of reuse to the timely restoration and maintenance of safe healthcare services. Its relevance depends on

whether reused equipment meets clinical requirements and can be reliably integrated into healthcare facilities. The institutional dimension connects these processes by determining whether equipment can be identified, assessed, documented, certified, and redistributed through coordinated procedures.

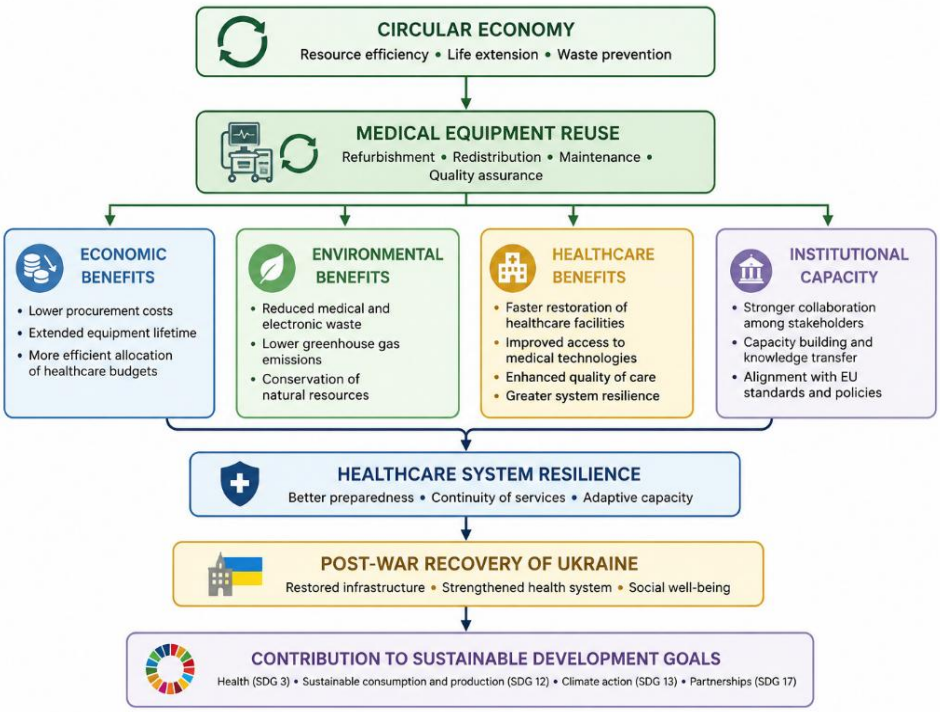
The framework is organised around four analytical dimensions: environmental, economic, healthcare, and institutional. Technical assessment, maintenance, refurbishment, certification, safety assurance, and traceability are treated as cross-cutting implementation requirements that influence the feasibility of reuse across all four dimensions. Without adequate technical and regulatory capacity, potential economic, environmental, and healthcare benefits cannot be effectively realised.

For Ukraine, fragmented procedures, incomplete maintenance documentation, limited technical capacity, and weak coordination may constrain the development of systematic reuse. Conversely, quality assurance procedures, technical training, traceability mechanisms, and further alignment of the regulatory framework with European requirements may create more favourable conditions for safe and scalable implementation. Ukraine's recent regulatory developments, including Resolutions № 758 and 759 adopted in June 2026, should also be taken into account when further developing approaches to the management and regulation of medical technologies [Cabinet of Ministers of Ukraine 2026a; Cabinet of Ministers of Ukraine 2026b]. These interdependencies provide the basis for the conceptual framework presented in Figure 1.

The framework conceptualises medical equipment reuse as an integrating mechanism connecting circular economy principles with healthcare recovery. Its central proposition is that the potential contribution of reuse depends on the interaction of economic, environmental, healthcare, and institutional dimensions rather than on any single benefit.

The economic and environmental dimensions address the potential retention of financial, material, and functional value through the continued use of suitable equipment. The healthcare dimension relates this process to the restoration and resilience of healthcare services, while the institutional dimension provides the governance and organisational conditions required for reuse to operate beyond isolated initiatives.

Figure 1. Conceptual framework of medical equipment reuse as a strategic mechanism for sustainable healthcare recovery in Ukraine



Source: developed by the author based on the author's original ideas and research objectives; ChatGPT was used solely for the graphical visualization of the author-developed conceptual framework.

The relationship between these dimensions is reinforcing but conditional. More efficient use of existing equipment may reduce pressure on procurement budgets and preserve material value. At the same time, the feasibility of reuse depends on appropriate technical expertise, safety procedures, regulatory oversight, and coordination among relevant stakeholders. Institutional capacity therefore plays a central role in determining whether individual reuse activities can develop into a systematic component of healthcare recovery.

This interpretation is consistent with research that positions circular healthcare as a broader systemic transition involving healthcare institutions, supply chains, and policy frameworks [MacNeill et al. 2020]. The relevance of reuse is consequently not limited to waste reduction or environmental performance. Its potential significance lies in connecting resource efficiency with healthcare recovery and longer-term system resilience.

Importantly, the framework does not position reuse as a substitute for new medical equipment. New procurement remains necessary where technologies are obsolete,

damaged, clinically inadequate, or unable to meet current safety and performance requirements. The strategic role of reuse is instead to identify situations in which the functional value of existing equipment can be safely retained and incorporated into healthcare recovery processes.

Overall, the proposed framework positions medical equipment reuse as a strategic component of sustainable healthcare recovery rather than solely an environmental or waste-management measure. Its potential contribution arises from the interaction of economic, environmental, healthcare, and institutional dimensions, supported by cross-cutting technical and regulatory requirements. For Ukraine, this approach can connect immediate reconstruction needs with longer-term circular healthcare transformation by incorporating lifecycle-oriented management, refurbishment, redistribution, and appropriate governance into the management of medical technologies.

Conclusion

The transition towards a circular economy requires healthcare systems to move beyond traditional waste management and consider how the functional value of medical resources can be retained throughout their life cycle. This study suggests that medical equipment reuse can serve as a strategic mechanism linking circular economy objectives with sustainable healthcare recovery by connecting resource efficiency with the restoration and resilience of healthcare capacity.

The review indicates that the feasibility of reuse depends not only on the technical condition of available equipment but also on the regulatory, organisational, and institutional conditions under which assessment, maintenance, refurbishment, certification, and redeployment take place. Consequently, the potential contribution of reuse cannot be understood solely as an environmental or cost-saving measure. Its implementation requires coordinated technical capacity, quality assurance, traceability, appropriate procurement mechanisms, and institutional cooperation.

For Ukraine, the relevance of this approach extends beyond conventional environmental objectives. In the context of post-war recovery, medical equipment reuse can complement new procurement by incorporating refurbishment, redistribution, and life-extension strategies into broader healthcare reconstruction processes. Such an approach may support the restoration of healthcare capacity while promoting more efficient use of limited financial and material resources.

The principal scientific contribution of this study lies in addressing an underexplored area of Ukrainian healthcare research through a four-dimensional conceptual framework integrating economic, environmental, healthcare, and institutional dimensions of medical equipment reuse. The framework highlights that the potential contribution of reuse depends on the interaction of these dimensions,

while technical and regulatory capacities function as cross-cutting conditions for its safe and systematic implementation.

From a policy perspective, further development of medical equipment reuse mechanisms in Ukraine should build on existing and emerging regulatory reforms while strengthening technical standards, certification and traceability procedures, lifecycle-oriented procurement, and refurbishment capacity. Future research should provide empirical evidence on the cost-effectiveness, environmental impacts, technical performance, and institutional feasibility of reuse programmes in the context of post-war healthcare recovery.

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PART II. ORGANIZATIONS AND STRATEGIC TRANSFORMATION

Wang S.S., Majchrzak M. (2026), Strategic Dilemmas in the Green Transition of Chinese and Polish Energy Enterprises [in:] Piekut, M., & Luque Vílchez, M. (Eds.), Organizations, People and Sustainable Transformation in Times of Change, Kolegium Nauk Ekonomicznych i Społecznych, Politechnika Warszawska, Płock.

STRATEGIC DILEMMAS IN THE GREEN TRANSITION OF CHINESE AND POLISH ENERGY ENTERPRISES

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Streszczenie

Napędzani neutralnością węglową i trzecią transformacją energetyczną przedsiębiorstwa energetyczne wymagają zielonej przebudowy. Chiny i Polska wprowadziły wspierające regulacje, ale nadal występują istotne przeszkody. Badanie tworzy czterowymiarowy schemat, buduje system oceny metodą współczynnika zmienności i przeprowadza analizę empiryczną firm energetyki tradycyjnej i odnawialnej z obu krajów. Potwierdza różnice międzykrajowe oraz heterogeniczność branżową w trudnościach transformacyjnych, analizuje ich przyczyny, przedstawia sugestie, uzupełnia badania nad transformacją energetyczną i dostarcza praktycznych wskazówek dla ich branż energetycznych.

Słowa kluczowe: zielona transformacja; energia odnawialna; różnice międzykrajowe; heterogeniczność branżowa

Summary

Driven by carbon neutrality and the third energy transition, energy companies need green transformation. Though China and Poland enacted supportive policies, significant barriers remain. This study builds a four-dimension framework, uses the coefficient of variation method for evaluation system construction, and empirically examines traditional and renewable energy firms from the two countries. It confirms cross-country differences and industrial heterogeneity in transformation difficulties, analyzes causes, proposes advice, supplements energy transition research and provides practical guidance for their energy sectors.

Key words: Green Transformation; Renewable Energy; Cross-country Differences; Industry Heterogeneity

JEL: Q4, Q5, L2, O13

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Introduction

Amid global warming, carbon neutrality goals and geopolitical volatility, the global energy system is undergoing a third green transformation. China released dual-carbon policies in 2021 and launched renewable energy substitution programs in 2024 to strengthen energy security. In response to the European Green Deal, Poland has phased out high-carbon facilities and promoted energy diversification and independence since 2020.

Despite initial achievements, energy enterprises in both countries are hindered by path dependence, high costs, technical bottlenecks and market fluctuations. Existing research mostly covers macro policies and Western European comparisons, lacking micro-level China-Poland comparative studies. This paper empirically identifies cross-country and industrial gaps in green transition, constructs a theoretical framework and research hypotheses, and offers references for bilateral energy development and cooperation.

The contributions of this paper lie in expanding market size theory and institutional theory, examining the dual heterogeneity of national contexts and energy enterprise characteristics, revising the applicable boundaries of the theories in the energy sector, improving the analytical framework for the green transition of energy enterprises, and offering new perspectives and practical references for the comparative study of China-Poland energy transition and bilateral energy cooperation.

1. Literature review

The first and second energy transitions reshaped the energy structure from biomass to fossil fuels, then further to oil and natural gas. Currently, the world is undergoing the third energy transition, which centers on shifting the energy structure toward low-carbon energy sources (Fouquet & Pearson, 1998; Allen, 2009; Grübler et al., 1999). Essentially, the green energy transition represents the practical implementation of sustainable transition in the energy sector. It is a systematic, long-term and fundamental social structural transformation requiring joint efforts from multiple stakeholders, as well as a structural adjustment driven by policies and institutional reforms. Therefore, its success hinges on a stable institutional framework and multi-participant engagement (Markard et al., 2012; Matthes, 2017). To guarantee policy implementation, capital monopoly must be prevented. Only precise alignment between long-term objectives and market mechanisms can deliver in-depth energy transition at low costs (Tanaka & Chen, 2013; Shayegh & Sanchez, 2021). Existing studies have revealed substantial divergence in energy transition paths across different countries (Hou et al., 2021). Characterized by high coal reliance, enormous energy demand, robust technological capabilities and strong policy backing, China faces both opportunities and challenges in its energy transition. Accordingly, carbon emission

reduction and the popularization of renewable energy constitute the core priorities of China's energy transformation (Zhao et al., 2022; Li et al., 2024). As the largest-scale renewable clean energy source, hydropower is irreplaceable. Despite constraints on its development, establishing a joint dispatching system integrating hydropower, wind power, photovoltaic power and energy storage represents the future development direction (Feng et al., 2022). To achieve the carbon neutrality goal, overall policy coordination is essential, alongside leveraging the strengths of green finance and taking China's unique regional disparities into full consideration (Tan et al., 2024; Liu et al., 2025; Su & Fan, 2022). Poland is endowed with abundant renewable energy resources and boasts long-term development potential. Nevertheless, the share of renewable energy in its primary energy consumption remained low in the initial transition stage, mainly due to high development costs, insufficient technical support and limited public awareness (Paska et al., 2009; Paska & Surma, 2014). Energy transition can inject new impetus into Poland's economy and boost technological progress and employment growth. However, path dependence, excessive transition costs and public resistance remain major obstacles (Wojtkowska-Łodej, 2021; Mrozowska et al., 2021). At present, insufficient grid connection capacity for high and low voltage power grids in Poland restricts the development of nuclear power, which hinders the overall transition arrangement and poses threats to national energy security (Ligus, 2025). Overall, both China and Poland have achieved phased progress in the green energy transition, yet challenges persist in subsequent development. Traditional energy enterprises are plagued by high costs, technical bottlenecks, organizational inertia, talent shortages and financing difficulties (Karaeva et al., 2023). Renewable energy enterprises are trapped in development predicaments stemming from inadequate policy support and lengthy approval procedures (Juszczyk et al., 2022). Existing studies indicate that China cannot realize large-scale grid integration of new energy at present, so the orderly phase-out of coal-fired power and the expansion of new energy capacity must be carried out simultaneously. Restrained by coal dependence and high sensitivity to energy prices, Poland faces prominent obstacles in its energy transition (Manowska et al., 2024; Wojtaszek et al., 2024).

In summary, both China and Poland are confronted with notable difficulties in the green energy transition. Existing research mostly focuses on individual countries or comparisons within the EU, while few comparative studies have targeted China and Poland, which motivates the present research.

2. Theoretical Framework and Hypotheses

Institutional theory suggests that differences in history and informal norms lead to divergent institutional environments across countries (North, 1990). Transition theory provides an analytical framework for multi-stakeholder and nonlinear technological

change (Geels & Schot, 2007). Accordingly, we propose H1. The regulative pillar of institutions imposes mandatory binding constraints (Scott, 1995). Energy justice requires energy transitions to balance public interests and equity with supportive policies (Sovacool & Dworkin, 2015). Constrained by EU regulations, Poland faces stricter transition constraints, thereby forming H2. Industry competition and supply–demand dynamics generate universal operational pressure, while cost structure heterogeneity widens inter-firm competitiveness gaps (Porter, 2008), thereby forming H3. Path dependence theory argues that economic and technological standards are locked by historical choices and positive feedback (Arthur, 1989). Differences in market scale and development demands between China and Poland lead to H4. Market size theory holds that output scale reduces unit production costs and drives corporate strategic adjustments (Krugman, 1980), thereby forming H5. Energy transition triggers fossil fuel asset stranding (Carney, 2015). While traditional energy firms face multifaceted practical constraints in transition, renewable energy enterprises are mainly hampered by policy factors (Chasin et al., 2020; Østergaard et al., 2020), thereby forming H6. Therefore, the following hypotheses are proposed:

H1. There are differences in the progress of green transformation among energy enterprises in China and Poland.

H2. Policy constraints vary between the two countries.

H3. Enterprises in both nations confront cost pressures yet differ greatly in internal structures.

H4. Technological development paths vary markedly.

H5. Market size shapes divergent corporate strategies for energy firms in the two nations.

H6. The dilemma paths of traditional energy and renewable energy enterprises differ significantly.

3. Research Design and Methodology

This paper selects China Shenhua Energy Co., Ltd., China Three Gorges New Energy (Group) Co., Ltd., Polska Grupa Energetyczna S.A. and Polenergia S.A. as research samples due to their reliable data and strong representativeness.

This study uses 2021–2025 data to build a transition dilemma evaluation index system. After extreme value standardization and coefficient of variation weighting, comprehensive scores are calculated. It horizontally compares dilemma intensity among sampled firms, identifies transition obstacles in both countries, and conducts industrial heterogeneity analysis. Finally, it summarizes prevailing problems and proposes targeted countermeasures.

This paper constructs a research framework and identifies the factors contributing to cross-country and industrial disparities in the green transition of

energy enterprises between China and Poland (Figure 1).

Figure1 Heterogeneity Model of Energy Transition

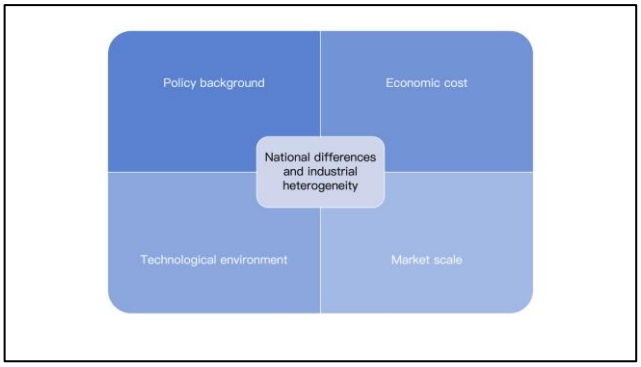

Table1. Comprehensive Evaluation Indicators of Green Transition Dilemma

First-level Dimension	Second-level Indicator	Code	Attribute
Policy Constraint	Carbon Emission Intensity	X_1	Positive
	Env. investment-to-revenue ratio	X_2	Positive
	Number of environmental penalties	X_3	Positive
Economic Cost	Green Investment Intensity	X_4	Positive
	Asset-Liability Ratio	X_5	Positive
	Return on Net Assets	X_6	Negative
Technological Innovation	R&D Investment Intensity	X_7	Positive
	New patent grants	X_8	Negative
	Ratio of Technical Staff	X_9	Negative
Market Strategy	Green Power Ratio	X_{10}	Negative
	Overseas Income Ratio	X_{11}	Negative
	New installed capacity of new energy	X_{12}	Negative

Source:Annual reports, ESG reports and officially disclosed industrial data of enterprises

This study establishes an evaluation system consisting of 12 quantitative indicators (Table 1).

Data processing is conducted following the formulas to obtain the final scores (Table 2).

Table 2. Main Calculation Formulas

1	2	3	4	5	6
$x'=\frac{x-x_{\min}}{x_{\max}-x_{\min}}$ $x'=\frac{x_{\max}-x}{x_{\max}-x_{\min}}$	$\bar{x}_j=\frac{1}{n}\sum_{i=1}^{n}x'_{ij}$	$\sigma_j=\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x'_{ij}-\bar{x}_j)^2}$	$CV_j=\frac{\sigma_j}{\bar{x}_j}$	$w_j=\frac{CV_j}{\sum_{j=1}^{m}CV_j}$	$S_i=\sum_{j=1}^{m}w_j x'_{ij}$

Note: x' = normalized value of the indicator; x = original value of the indicator; x_{max} = maximum value in the sample; x_{min} = minimum value in the sample; $\bar{x}_j$ = Mean value of the j-th indicato; x'_{ij} = Original standardized value of indicator j for sample i; σ_j = Standard deviation of the j-th indicator; CV_j = Coefficient of variation of the j-th indicator; w_j = Weight of the j-th indicator; S_i = Comprehensive score of sample i

4. Results and Discussion

All variables are winsorized at the 1% and 99% percentiles to eliminate outlier interference. The data shows no substantial changes before and after treatment, confirming robust conclusions. The national and sectoral comprehensive scores are calculated as the average scores of corresponding sample enterprises (Table 3).

Table 3 Green Transition Difficulty Score by Country & Energy Type

Code	**China**	**Poland**	**Traditional energy**	**Renewable energy**	**Severe transition predicaments**
X_1	0.18	0.195	0.2	0.175	Poland & Traditional
X_2	0.195	0.2	0.215	0.18	Poland & Traditional
X_3	0.195	0.105	0.1	0.2	China & New
X_4	0.205	0.205	0.225	0.185	Same & Traditional
X_5	0.19	0.215	0.22	0.185	Poland & Traditional
X_6	0.18	0.21	0.22	0.17	China & New
X_7	0.185	0.195	0.205	0.175	Poland & Traditional
X_8	0.195	0.145	0.245	0.08	Poland & New

Code	China	Poland	Traditional energy	Renewable energy	Severe transition predicaments
X_9	0.18	0.205	0.2	0.185	China & New
X_{10}	0.195	0.225	0.235	0.185	China & New
X_{11}	0.195	0.225	0.22	0.2	China & New
X_{12}	0.205	0.2	0.215	0.19	Poland & New

The results show distinct transition predicaments in both countries' energy sectors, confirming gaps between developed and emerging economies and the absence of a unified low-carbon transition standard (Tick et al., 2024; Geels & Schot, 2007). This paper extends institutional theory to micro energy research and supplements perspectives from non-Western emerging economies (Zimmermann, 2024), Hypothesis 1 is verified.

According to the aggregate scores of the three indicators, Poland is under severe transition pressure due to dual policy constraints and domestic energy structure mismatches (Kazak et al., 2023). Despite EU funding support, inequalities persist. As a heavily coal-reliant economy, it faces mounting economic strain from unbalanced rights and obligations (Trépanier et al., 2025). These findings align with energy justice theory and verify Hypothesis 2.

In terms of capital conditions, China and Poland face comparable overall transition difficulties yet differ structurally. Polish energy enterprises carry heavy debts for equipment renovation; tighter carbon quotas crowd their liquid funds and lift industrial leverage ratios (Nawrocki & Jonek-Kowalska, 2023). Chinese firms suffer narrowed profit margins due to falling electricity prices and public energy supply obligations. These results corroborate the industrial cost structure theory and verify Hypothesis 3.

In the technical dimension, the two countries differ notably in technological path dependence, with Poland facing more severe transition difficulties. Polish energy enterprises hold few independent R&D patents and its R&D investment in clean energy has stagnated (Wojtkowska-Łodej & Jakubów, 2022; Gajdzik et al., 2025). By contrast, China prioritizes independent R&D guided by relevant policies. This result validates the technological dependence theory that overreliance on existing technologies and institutional inertia hinder innovation (Arthur, 1989; North, 1990), and confirms Hypothesis 4.

China faces greater pressure in market scale. Though both countries rely heavily on coal, the huge gap in installed thermal power capacity rules out large-scale coal

unit shutdowns in China. Amid the Russia-Ukraine conflict, Poland prioritized energy sovereignty, restricted overseas expansion and focused on its domestic market. The results confirm that market size shapes corporate investment structure (Krugman, 1991). Contrary to the traditional view that overseas deployment expands market capacity, this study incorporates international shocks and finds excessive overseas expansion hinders energy transition, revising the theory's scope of application (Youno, 1928). Hypothesis 5 is verified.

The overall indicator scores reveal prominent disparities in transition difficulties between traditional and renewable energy enterprises. Constrained by massive coal stock assets, traditional energy firms suffer squeezed profits from heavy capital outlays, which triggers financing constraints and impedes green upgrading and R&D innovation. Renewable energy enterprises are stuck in expansion bottlenecks due to talent shortages, unstable output of wind and photovoltaic power, and low transformation incentives. The results back the stranded asset theory that high-carbon assets incur financial shocks from asset stranding and damage corporate profitability and financing capacity (Daumas, 2024). Hypothesis 6 is verified.

Conclusion

The conclusions show that both China and Poland are hampered in energy green transition with remarkable national and industrial gaps, transmitted through policy, cost, technology and market scale channels. Poland is restrained by policy constraints, high debt and insufficient innovation, while China struggles with limited profits, inefficient investment and massive rigid power demand. Additionally, traditional energy enterprises are trapped by high carbon emission intensity, whereas renewable energy firms face barriers to business expansion.

Accordingly, targeted development suggestions are proposed in this study:

First, Poland should optimize capital allocation, reduce debt pressure with revenues from new energy projects, boost technological R&D and rationalize energy layout, so as to elevate its voice in global energy governance.

Second, China's energy industry needs to optimize the assessment system, focus on developing core technologies, coordinate the development of fossil and clean energy, and balance power supply security and low-carbon transition.

Third, traditional energy enterprises should phase out high-carbon facilities step by step, while renewable energy firms should carry out staff retraining and pursue rational expansion.

Despite the obtained results, the study has certain limitations. First, the sample size is small and only includes large listed firms, which may affect representativeness. Second, it mainly focuses on policy differences, without deeply exploring institutional and cultural factors. Therefore, future research should expand the sample size and

enterprise categories, and incorporate institutional and cultural factors into cross-country analysis to improve the representativeness of findings.

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FORMATION OF AN ENTERPRISE'S PRODUCTION STRATEGY UNDER THE CONDITIONS OF A CIRCULAR ECONOMY

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Streszczenie

Artykuł poświęcono opracowaniu teoretycznych i aplikacyjnych podstaw kształtowania oraz wyboru strategii produkcyjnej przedsiębiorstwa w warunkach gospodarki o obiegu zamkniętym. Aktualność badań potwierdza fakt, że istniejące modele rozwoju zorientowane na wartość doprowadziły do znacznego wyczerpania zasobów naturalnych oraz nadmiernego obciążenia środowiska szkodliwymi odpadami, zagrażając prawidłowemu funkcjonowaniu przedsiębiorstw, gospodarek narodowych i całego społeczeństwa. W badaniu usystematyzowano podejścia do interpretacji pojęcia „gospodarka o obiegu zamkniętym" według kryteriów klasyfikacyjnych, odróżniono je od pokrewnych koncepcji zrównoważonego rozwoju oraz doprecyzowano jego istotę poprzez wyodrębnienie dwóch komponentów: ogólnego i szczegółowego. Uzasadniono kluczową rolę strategii produkcyjnej w kompleksie strategii funkcjonalnych przedsiębiorstw działających w warunkach gospodarki o obiegu zamkniętym. Autorzy proponują doprecyzowaną definicję „strategii produkcyjnej", uwzględniającą zasady gospodarki o obiegu zamkniętym. Przeprowadzono analizę wdrażania modeli biznesowych o obiegu zamkniętym przez przedsiębiorstwa krajowe i zagraniczne, ujawniając najważniejsze wyzwania w krajowym zarządzaniu strategicznym. W artykule przedstawiono naukowo-metodyczne podejście do kształtowania strategii produkcyjnej przedsiębiorstwa w oparciu o zasady gospodarki o obiegu zamkniętym, obejmujące mechanizm określania modelu zachowania przedsiębiorstwa oraz trójwymiarowy model wyboru strategii produkcyjnej. Zaproponowaną klasyfikację strategii produkcyjnych w warunkach gospodarki o obiegu zamkniętym oraz współczynnik efektywności integracji przedstawiono jako narzędzia o zastosowaniu praktycznym. Zaproponowane podejście zastosowano w przedsiębiorstwach rolniczych obwodu lwowskiego.

Słowa kluczowe: strategia produkcyjna; gospodarka o obiegu zamkniętym; model zachowania przedsiębiorstwa; modele biznesowe gospodarki o obiegu zamkniętym; zdolności integracyjne przedsiębiorstwa; zabezpieczenie zasobowe.

Summary

The article is devoted to the development of theoretical and applied foundations for the formation and selection of an enterprise's production strategy under the conditions of a circular economy. The relevance of the research is confirmed by the fact that existing value-oriented development models have significantly depleted natural resources and oversaturated the environment with harmful waste, threatening the normal functioning of enterprises, national economies, and society as a whole. The study systematises approaches to interpreting the concept of 'circular economy' by classification feature, distinguishes it from related

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sustainability concepts, and clarifies its essence through two components: general and specific. The pivotal role of the production strategy within the functional strategy complex of enterprises operating in circular economy conditions is substantiated. The authors propose a refined definition of 'production strategy' that incorporates circular economy principles. An analysis of circular business model implementation by domestic and foreign enterprises is conducted, revealing key challenges in domestic strategic management. The article presents a scientific-methodological approach to forming the production strategy of an enterprise based on circular economy principles, including the mechanism for determining the enterprise's behaviour model and a three-dimensional model for selecting the production strategy. The proposed classification of production strategies under circular economy conditions and the integration efficiency coefficient are introduced as practical tools. The proposed approach is applied to agricultural enterprises in the Lviv Region.
Keywords: production strategy; circular economy; enterprise behaviour model; circular business models; enterprise integration capabilities; resource provision.

JEL: M11, L23, Q01, Q56

Introduction

Modern operating conditions for enterprises are characterised by large-scale climate change, wars, limited natural resources, and their irrational use over long periods. These challenges require accelerating the transition to a new development model and expanding the application of circular economy (closed-loop economy) solutions. The implementation of circular economy principles encourages enterprises to take measures to reduce waste, use natural resources more rationally, and reduce environmental pollution, which accordingly shifts priorities in enterprise development aspects when forming long-term competitive advantages.

The competitive strategic development of an enterprise in a circular economy context is based on a rationally formed product range, opportunities to reduce waste, optimise resources, rationalise business processes, and build effective cooperation with prospective partners based on a defined strategic reserve of a certain type of potential. Therefore, the production strategy plays a decisive role in enterprise activity, representing a long-term programme of specific actions for creating and implementing a competitive product, while directing efforts towards the optimal use and development of all capacities to achieve a strategic competitive advantage.

The implementation and use of circular economy principles by domestic enterprises remain at an embryonic stage, and the processes of strategy formation and implementation, particularly production strategies, are not prioritised. Therefore, the issue of forming production strategies under circular economy conditions is highly relevant, especially in the context of European integration processes and post-war economic recovery.

Production strategy has been discussed as a long-term programme of decisions and actions linking production capabilities with enterprise development and competitive objectives [Kovtun 2005; Miziuk 2009; Omelianenko and 2004 2012; Kuzmin and Petryshyn 2009; Kolenda 2017; Thompson and Strickland 2002].

Circular economy research has developed across several complementary streams, including resource security, sustainability, business model transformation and enterprise-level implementation [Hislop and Hill 2011; Zvarych 2019; Gorbal and Lomaha 2022; Geissdoerfer et al. 2017; Korhonen et al. 2018].

Although the literature on the circular economy has expanded considerably, studies on circular business models, production strategies and enterprise resource capabilities are frequently conducted as separate research streams. Existing approaches explain the principles of circular value creation, resource recovery and business model transformation, but provide limited guidance on how an enterprise should simultaneously select a production strategy, determine a feasible model of circular behaviour and decide whether the required resources should be developed internally or obtained through cooperation with external stakeholders. This fragmentation is particularly relevant for enterprises operating under resource constraints, uncertainty and disrupted supply chains.

The research gap addressed in this article therefore concerns the lack of an integrated approach to the formation and selection of an enterprise's production strategy that combines circular business models, enterprise-specific operational capabilities and the capacity to integrate resources within inter-organisational relationships.

Accordingly, the main research question is formulated as follows:

How can an enterprise's production strategy be formed and selected by integrating circular business models, the enterprise's feasible behaviour model and its capacity for internal or external resource provision?

The article has a conceptual and methodological character and is supplemented by an empirical illustration based on agricultural enterprises in the Lviv Region. The empirical component is intended to demonstrate the applicability of the proposed approach rather than to provide its final statistical validation.

The objective of the article is to develop an integrated conceptual and methodological approach to the formation and selection of an enterprise's production strategy under circular economy conditions.

The original contribution of the article consists of four interrelated elements:

1. a mechanism for determining an enterprise behaviour model under circular economy conditions;
2. an integration efficiency coefficient supporting the choice between internal resource provision and cooperation with external stakeholders;

3. a three-dimensional model for selecting a production strategy by combining the circular business model, enterprise behaviour model and integration capability level;
4. a classification of production strategies adapted to the requirements of the circular economy.

1. Theoretical foundations: circular economy and production strategy

1.1. Classification of Circular Economy Concepts

The conditions of modern enterprise functioning, which represent a synthesis of globalisation, the fourth industrial revolution, growing inequality, worsening ecological problems, and growing political uncertainty, require searching for tools to ensure the balance of economic and ecological interests. This has stimulated, since the mid-twentieth century, the search for alternative solutions to ensure economic growth and societal welfare through the transition from a linear development model to new economic models oriented towards overcoming ecological challenges.

In the scientific literature, interpretations of the concept of 'circular economy' differ in their scope, level of analysis, expected outcomes and implementation principles [Gurieva 2019; Hislop and Hill 2011; Ellen MacArthur Foundation 2015; Zhijun and Nailing 2007; Yuan et al. 2006; Kulczycka 2019; Murray et al. 2017; Kirchherr et al. 2018; Geissdoerfer et al. 2017; Ghisellini et al. 2016]. Based on an analysis of these definitions, they can be classified according to classification features related to the key categories of content:

- type of affiliation – model, economy, alternative, concept/philosophy, system, initiative, activity, basis, strategy, method/way, approach, template;
- breadth of coverage – global, national, specific (within a particular business entity);
- results obtained – reduction of environmental risk; maximisation of human welfare and ecosystem efficiency; achievement of sustainable development; optimisation of material and energy cycles;
- implementation principles – resource orientation; waste orientation; cycle orientation.

The analysis of these classification groups shows that it is most appropriate to interpret the concept of 'circular economy' as a model, since a model is a representation of a real object, system, or concept in a form that allows scenario analysis and forecasting.

A comparative analysis of linear economy, sustainable development, circular economy, and green economy reveals the unique features of each and their complementary nature (Table 1).

Table 1. Comparative Analysis of Linear Economy and Main Concepts of Environmental Economics

Parameters	Linear Economy	Sustainable Development	Circular Economy	Green Economy
Main causes of transition	Economic, techno-logical	Economic, social, ecological	Resource; techno-logical; socio-economic; ecological	Ecological
Key subject	Person as creator of value and waste	Person as key subject of socio-ecological-economic processes	Person as guarantor of waste prevention	Person as ecologist
Main features	Linear 'take-make-waste' model; excessive resource consumption	Triad of social, economic, ecological systems; balanced development	Minimisation of primary material consumption; maximisation of recycled resources	'Green growth'; sustainable development driven by innovation
Key advantages	High profits and low prices	Resource efficiency; improved product quality; social acceptability	Waste reduction; resource optimisation; innovation stimulation; cost savings	Reduction of toxic emissions; support for green technologies; natural capital restoration
Key challenges	Does not account for waste costs; rapid depletion of resources and ecosystems	Expensive and complex business model transformation; long implementation timeline	Need to adapt to new circular model; new professional skills required	Insufficient business awareness; weak strategic planning for green investment

Source: compiled by the authors based on [Valko 2018; Geissdoerfer et al. 2017; Heshmati 2018; Korhonen et al. 2018; Sauve et al. 2016; Weizsäcker and Wijkman 2019].

Based on the study of the place of circular economy among related concepts [Maslak and Zalutska 2024], the authors propose a dual interpretation:

From the general perspective, the circular economy is a type of economy whose goal is the balanced development of society by increasing the welfare of a country (city, region, population), ensuring social justice, and reducing environmental risks through the construction of circular (cyclical) models of a socially integrated society.

From the specific perspective, the circular economy is a development model for a business entity oriented towards creating value and utility using closed resource flows

(cycles), focused on maximising resource use efficiency and minimising waste in the context of balanced economic, ecological, and social development.

This dual interpretation allows identifying the key aspects of the circular economy at each level of simple and complex societal development cycles, thereby strengthening the transparency and clarity of models and the efficiency of systems in building a socially integrated society.

1.2. Production Strategy: Concept and Role

The analysis of existing interpretations of 'production strategy' reveals that it can be characterised from several perspectives: as a long-term action programme; a set of decisions; a management plan; a process of production reorganisation; a policy for placing capacities and using resources. Based on the advantages of each approach and the conditions of functioning of modern enterprises, the authors refine the concept as follows: [Maslak and Zalutska 2022].

A production strategy is a long-term programme of actions of the key (core) component of functional strategies, aimed at ensuring the strategic competitive potential of an enterprise through the effective enhancement of its production component by an efficient production system, by rationalising the enterprise's product portfolio through balancing external (market) needs, trends, proposals, internal capabilities and relationships with attractive stakeholders, taking into account the principles of circular economy (elimination or reduction of waste and pollution, restoration of natural systems, keeping products and materials in constant use).

The key role of the production strategy within the functional strategy complex is substantiated by the fact that in the context of circular economy requirements, it is the production strategy that creates the foundation for other functional strategies. It focuses on optimising production processes, rationalising business processes, reducing waste, and reducing enterprise dependence on external stakeholders. Under war conditions and post-war recovery, this significance is further amplified, as enterprises must maximise self-sufficiency and form closed production cycles [Maslak and Zalutska 2023].

The proposed understanding of production strategy is consistent with several complementary perspectives in strategic management [Kovtun 2005; Miziuk 2009; Thompson and Strickland 2002]. The resource-based perspective emphasises the role of enterprise-specific resources and capabilities in building competitive advantage, while the value chain perspective directs attention to the configuration of production activities and material flows. Circular business model theory explains how value can be created and retained through resource recovery, product life extension and closed-loop solutions [Lewandowski 2016; Lieder and Rashid 2016; Tukker 2015]. From this perspective, production strategy links internal resources, operational processes and

inter-organisational cooperation, thereby translating circular economy principles into specific strategic decisions.

2. Research methodology and analytical support

2.1. Research Design

The study adopts a conceptual and methodological research design supported by descriptive, survey-based and case-based empirical analysis. The research process comprised four stages.

First, a critical analysis and synthesis of the literature were conducted to identify the main interpretations of the circular economy, production strategy and circular business models.

Second, the implementation of circular economy principles by foreign and domestic enterprises was analysed. The analysis of foreign enterprises was based on publicly available company reports, sectoral studies and previous research. The cases presented in Table 2 were selected as representative examples of different circular business models and levels of strategic integration.

Third, the authors conducted a survey of 750 respondents representing enterprises from real estate, construction, e-commerce, services, agriculture, medicine, IT and logistics. The survey was carried out from 1 to 30 November 2023. It examined the time horizon of strategic planning, operational capacity, changes in product and market strategies, and the extent to which enterprises analysed market demand and competitors.

Fourth, the proposed conceptual and methodological approach was applied to 20 agricultural enterprises in the Lviv Region. The enterprises were assessed using indicators concerning inventory changes, utilisation of production equipment and agricultural land, profitability and the share of material costs in total production costs. These indicators provided the basis for assigning each enterprise to the most appropriate behaviour model. KSP 'Hriada' was subsequently selected as an illustrative case for a more detailed assessment of the proposed production strategy and its financial viability.

The empirical component constitutes an initial application of the proposed approach. Its purpose is to demonstrate the logic and practical usefulness of the model rather than to provide its final statistical validation.

The respondents were selected using purposive sampling and included enterprise owners and managers. Data were collected through a structured questionnaire and analysed using descriptive statistics.

2.2. Implementation of Circular Business Models

The relevance of circular economy principles is confirmed by the catastrophic impact of waste on the quality and duration of life of society. According to the 2021 Circularity Gap Report, the linearity of the global economy results in a circularity rate of only 8.6% globally. World Bank projections indicate that by 2030, the amount of waste could reach 2.58 billion tons, and by 2050 – 3.77 billion tons.

Ukraine faces a critical waste problem: some landfills are already 80-95% full, and the country produces over 474 million tons of waste per year, of which 448 million tons is hazardous. Since the large-scale invasion in 2022, Ukraine has suffered significant environmental damage: in the first six months alone, environmental losses amounted to UAH 395 billion.

In the context of these challenges, the following circular business models have been identified as key tools for enterprises (Accenture classification):

- Circular supply chains – substituting scarce non-renewable inputs with fully renewable, recyclable, or biodegradable inputs;
- Recovery and recycling – recovering useful resources from goods at end-of-use and recycling materials after consumer use;
- Product life extension – using repair, upgrade, remanufacturing, and remarketing to extend product lifespan;
- Sharing platforms – enabling increased utilisation by making under-utilised assets accessible to other users;
- Product as a service – offering products as services through pay-per-use or leasing models.

An analysis of foreign and domestic enterprises indicates that foreign companies more frequently and comprehensively develop and implement strategies based on circular economy principles, while domestic enterprises tend to apply circular economy principles at selected operational levels or stages. Table 2 presents eight representative international cases illustrating different approaches to circular economy strategy implementation.

Table 2. Characteristics of Selected International Enterprises' Circular Economy Strategies

No.	Enterprise	CE Goal	CE Effect Achieved	Goal Achievement	CE Coverage of Strategy
1	Renault	Carbon neutrality by 2050	Reduced CO_2 emissions; additional income from refurbished spare parts	Partial with corrections	Full

No.	Enterprise	CE Goal	CE Effect Achieved	Goal Achievement	CE Coverage of Strategy
2	Michelin	100% renewable materials by 2050	Extended tyre life; clients become long-term partners	Fully achieved	Full
3	IKEA	Innovative circular products by 2030	Reduced environmental footprint; zero landfill waste; material cost savings	Fully achieved	Full
4	Philips	25% revenue from circular products	Reduced hazardous materials pollution; reuse of scarce and expensive materials	Fully achieved	Full
5	Carlsberg	30% reduction in product carbon footprint; 50% reduction in water use by 2030	15% carbon footprint reduction; 21% water consumption reduction (2022 vs 2015)	Fully achieved	Full
6	H&M	100% recycled materials by 2025	17.9% recycled materials in production; 27.8% reduction of plastic packaging	Partially achieved	Partial
7	Feralpi	94% secondary raw material use	Reduced waste disposal costs; access to green financing; metallic waste recovery	Fully achieved	Full
8	Coca-Cola / PepsiCo	20-25% products in reusable packaging by 2030	Elimination of resource losses; increased production profitability	Fully achieved	Partial

Source: compiled by the authors based on [Ellen MacArthur Foundation 2017; European Commission 2014; Zlotnyk 2021; Gorbal and Lomaha 2022; Artemov et al. 2023].

The analysis confirms that enterprises that comprehensively integrate circular economy principles at all strategy levels achieve their goals more consistently. Foreign companies predominantly develop circular strategies at the corporate level, while domestic enterprises focus on functional and operational levels.

2.3. Challenges in Domestic Strategic Management

Based on a survey conducted from November 1–30, 2023 involving 750 respondents from various sectors (real estate, construction, e-commerce, services, agriculture, medicine, IT, logistics), the following key findings emerged:

- Only 26% of surveyed enterprises engaged in strategic planning with a horizon longer than one year;
- 62% of enterprises operated at full capacity, 24% with limitations;
- The most common strategic changes in 2023 were: reduction of product/service portfolio (31%), expansion of product lines (26%), entry into new markets (9%);
- Only 44% of domestic enterprises analyse market demand; only 38% analyse competitor strategies and prices;
- 39% of enterprises did not plan any strategic changes for the following year, considering their current strategy effective.

These challenges arise primarily from the intuitive formation and implementation of strategies as target guidelines rather than following a clear and consistent process that accounts for all stages of development, implementation, and realisation [Maslak et al. 2025].

3. Scientific-methodological approach to production strategy formation

3.1. Process of Production Strategy Formation

The proposed scientific-methodological approach to forming an enterprise's production strategy under circular economy conditions integrates two complementary sets of process stages. The first is a standard sequence common to strategic management: analysis of the external and internal environment, strategic choice, and implementation with monitoring. The second is a specialised sequence specific to circular economy conditions, encompassing the determination of the enterprise's development model, identification of the preconditions and motives for implementing circular economy principles, verification of enabling organisational conditions, and evaluation of the effectiveness of the resulting circular strategy set.

The effectiveness of the circular strategy set is assessed through a composite indicator that aggregates six distinct types of effects: economic (revenue growth, profitability, employment); ecological (waste reduction, decreased emissions, natural resource preservation); social (workforce welfare, income equity, community development); techno-technological (adoption of resource- and energy-saving technologies); resource (improved utilisation of material, land, and water resources);

and financial-investment (enhanced investment attractiveness and financial sustainability). Each effect type is weighted according to the priorities of the regional, sectoral, or national sustainable development plan within which the enterprise operates. This multi-dimensional assessment framework builds on earlier work concerning strategic development, production strategy and resource provision under circular economy conditions [Maslak, Zalutska and 2021 2023; Maslak et al. 2023]. This multi-dimensional assessment framework allows decision-makers to identify which dimensions of circular performance are lagging and to calibrate corrective strategic actions accordingly.

3.2. Enterprise Behaviour Model

A central and original element of the proposed approach is the concept of the enterprise behaviour model — a mechanism that allows each enterprise to identify the most feasible pathway for implementing circular economy principles given its specific resource endowment and operational constraints. Rather than prescribing a single universal circular business model, the approach recognises that enterprises differ substantially in their production structure, asset base, and market position, and should therefore adapt circular principles in ways that minimise disruption while maximising strategic gain.

Four behaviour models are identified. The first, creation of additional processing stages, is suited to enterprises that accumulate growing inventories of finished goods alongside declining profitability. By introducing downstream processing — such as oil production from sunflower crops or feed production from crop residues — an enterprise converts what would otherwise be waste or unsold stock into a value-generating product line. The second model, extension of exploitation duration, applies to enterprises with underutilised equipment or land. By diversifying the product mix to make fuller use of existing capacity — for example, introducing new crop varieties that allow more intensive land use throughout the agricultural calendar — the enterprise raises the productive life of its assets without requiring capital-intensive investment. The third model, reduction of non-recyclable waste, is particularly relevant to livestock operations, where biological waste can be systematically converted to organic fertiliser for crop cultivation, creating a closed-loop exchange of outputs and inputs. The fourth model, symbiosis, represents a combination of two or more of the above approaches and is appropriate for enterprises that possess the scale and organisational capacity to manage multiple circular loops simultaneously.

The selection among these models is not arbitrary but grounded in a quantitative assessment of three operational parameters: the efficiency of additional processing stages, measured as the proportional reduction in total waste relative to the pre-

intervention baseline; the efficiency of exploitation duration extension, measured as the proportional increase in the mean useful life of assets; and the waste utilisation rate, measured as the share of total waste that is productively recovered. These indicators provide managers with an objective basis for choosing the behaviour model that generates the highest aggregate efficiency gain given the enterprise's current situation.

3.3. Integration Efficiency and Resource Provision

Once the behaviour model has been selected, a further strategic decision concerns the structure of resource provision: whether the enterprise should produce the necessary inputs internally or source them from external partners. This make-or-buy decision is particularly important in the context of circular economy implementation, where some circular activities — waste processing, renewable energy generation, logistics for material return flows — may be beyond the technical capacity of individual enterprises to perform at sufficient scale or quality.

The integration efficiency coefficient may be expressed as:

$$IEC = E_{in}d / E_{in}t$$

where $E_{in}d$ denotes the total effect achievable through independent implementation and $E_{in}t$ denotes the total effect achievable through cooperation, including the direct effects of joint activities and the additional synergistic effect. The effects may be assessed in economic, resource, technological and organisational terms, depending on the type of circular activity under consideration.

To support this decision, the integration efficiency coefficient is introduced as a comparative measure. The coefficient compares the total effect achievable through independent implementation of the chosen circular activities against the combined effect obtainable through partnership with an attractive stakeholder. The combined effect encompasses not only the direct operational gains from the partnership but also the surplus — or spillover — effect that arises from the interaction itself: shared innovations, complementary competencies, access to new markets, and reputational benefits that neither party could achieve alone.

The interpretation of the coefficient provides clear decision guidance. A value below unity indicates that the enterprise lacks sufficient capacity to fully implement the intended circular activities independently, and that partnership or integration offers superior outcomes. A value equal to unity signals that the enterprise can achieve a closed production cycle on its own, without external dependence. A value above unity reveals that the enterprise possesses excess capacity relative to its circular commitments, making it a potential provider of resources or services to other entities — thereby enabling the construction of a complex multi-actor circular cycle that

extends beyond the individual firm to encompass entire supply chains, industrial parks, or regional economies.

4. Discussion

4.1. Three-dimensional model for production strategy selection

The proposed three-dimensional model integrates three complementary dimensions of production strategy selection under circular economy conditions:

- Circular business models – determined by higher-level strategies (region, industry, country, etc.);
- Enterprise behaviour model – based on existing and potential capabilities;
- Enterprise integration capability level – determined by the integration efficiency coefficient.

Existing circular economy frameworks usually focus on individual dimensions such as circular business model design, resource recovery, industrial symbiosis or product life extension [Lewandowski 2016; Lieder and Rashid 2016; Jiao and Boons 2014; Roos 2014; Tukker 2015]. The proposed approach differs by integrating three decision levels within one framework: the circular business model, the enterprise behaviour model and the enterprise's integration capability. Its added value lies in linking the strategic direction of circular transformation with the enterprise's operational conditions and the decision whether the required resources should be developed internally or accessed through cooperation.

The proposed classification of production strategies under circular economy conditions is structured according to four classification features:

Table 3. Classification of Production Strategies under Circular Economy Conditions

Classification Feature	Types of Production Strategies
By demand satisfaction	Green consumption strategy; eco-design strategy
By supply chain character	Tolling raw materials strategy; waste recovery strategy; circular material use strategy; circular supply strategy; extended flows strategy; resource recirculation strategy; material reverse flow management (life cycle extension; material recovery; multi-use in production cycles; recycling); industrial symbiosis strategy; exchange platform creation strategy
By production process state	Full specialisation; production reorientation; restorative cycles; closed cycles; production modification; limited specialisation; intensification; technological re-equipment; process change; manoeuvring; new production creation; moderate expansion; production improvement; renewal; stabilisation; innovative transformation; production flexibility; new value chain creation

Classification Feature	Types of Production Strategies
By R&D and organisational level	Property differentiation; assortment differentiation; innovative circular technology development; quality differentiation; product-to-service transformation; shared platform creation; product development; circular product design; virtual enterprise; global expansion; quality management; product life extension; product and component recycling

Source: developed by the authors.

4.2. Application to Agricultural Enterprises in the Lviv Region

The proposed approach was applied to 20 agricultural enterprises in the Lviv Region with primary activities in crop and livestock cultivation. The behaviour model selection was based on inventory change rates, equipment utilisation levels, land use intensity, and material costs as a share of production costs.

The results show that of the 20 enterprises studied: 9 should adopt the 'creation of additional processing stages' model; 8 should adopt the 'extension of exploitation duration' model; and 3 should adopt the 'symbiosis' model combining multiple behaviours.

As a representative case, the agricultural enterprise KSP 'Hriada' (KSP 'Gryada') was selected. Its financial indicators showed: declining inventory with no finished goods, low land utilisation (coefficient 0.65), and profit decrease of 21.12% in 2023 vs 2022. The recommended behaviour model was 'extension of exploitation duration' through product mix diversification.

For this enterprise, the introduction of rapeseed cultivation was proposed as a new product line based on:

- Availability of 140 ha of arable land suitable for rapeseed;
- High profitability of rapeseed cultivation (205% according to the Institute of Oilseed Crops), exceeding potato (by 100%), vegetables (by 111.1%), and sunflower (by 188.5%);
- Growing European interest in Ukrainian rapeseed (expected 12% shortage in the EU in 2024).

Given the enterprise's limited experience with rapeseed, integration with a partner enterprise (FH 'Smolyn') was proposed. The financial projections for KSP 'Hriada' under the circular economy production strategy are presented in Table 4.

The financial projections were prepared on the basis of the enterprise's historical financial data, the planned cultivation area, expected rapeseed yield, estimated selling prices, production costs and the investment required to implement the strategy. NPV and the profitability index were calculated for a five-year projection period using a 15% discount rate, reflecting the elevated investment risk and uncertainty of the operating environment.

Table 4. Key Performance Results of KSP 'Hriada' Before and After Circular Economy Production Strategy Implementation

No.	Indicator	2023 (actual), UAH thou.	2024 (planned), UAH thou.	2025 (planned), UAH thou.
1	Net revenue	1,042.1	1,292.1	1,792.1
2	Production cost	1,017.4	1,068.3	1,119.1
3	Pre-tax financial result	24.7	223.8	673.0
4	Net profit	–15.8	148.5	516.8
5	Net profit over 4 years	1,699.0 UAH thou.		
6	Discounted net profit over 5 years (15% discount rate)	1,416.1 UAH thou.		
7	Investment costs	1,219.2 UAH thou.		
	NPV (Net Present Value)	196.9 UAH thou.		
	Profitability Index (PI)	1.16		
	Payback Period	4.3 years		

Source: developed by the authors.

The positive NPV and profitability index above 1, along with a payback period of four years and three months, indicate the viability of the chosen circular economy production strategy. After five years, both enterprises would receive sustainable profits from rapeseed cultivation (profitability 24.8%, yield 31 c/ha) with additional net income of UAH 750 thousand, and could further develop processing facilities (glycerin, cake, oil, biofuel production).

The adopted production strategy under circular economy conditions allows the enterprise to obtain the following strategic advantages: stable profits; competitive product portfolio; waste reduction; extended land exploitation duration; production of ecologically clean products; and the potential to develop new processing industries.

Conclusion

The study has produced the following results and contributions:

1. The concept of 'circular economy' has been clarified and interpreted from two perspectives – general (macroeconomic) and specific (enterprise level). The typology of preconditions for transition to a circular economy has been extended to include requirements of national and global economies and war consequences as additional groups.

2. The pivotal position of the production strategy in the competitive long-term development of enterprises under circular economy conditions has been substantiated. It has been demonstrated that the rationalisation of internal business processes with production strategy as the priority allows enterprises to decide on the necessity of specific activities, their reduction, or reprofiling, and simplifies adaptation to dynamic operating conditions.
3. The definition of 'production strategy' has been refined to reflect the conditions of contemporary enterprises and circular economy development trends, specifically incorporating the principles of waste elimination, keeping products in use, and natural system regeneration.
4. A scientific-methodological approach to forming the production strategy of an enterprise based on circular economy principles has been developed, incorporating both standard and special process stages. The circular strategic set effectiveness indicator has been proposed, accounting for economic, ecological, social, techno-technological, resource, and investment effects.
5. The mechanism for determining the enterprise behaviour model (creation of additional processing stages; extension of exploitation duration; reduction of non-recyclable waste; symbiosis) and corresponding efficiency indicators have been proposed.
6. The integration efficiency coefficient has been introduced as a tool for rationalising the resource base and determining the optimal degree of partnership.
7. A three-dimensional model for selecting the production strategy has been developed, based on circular business models, enterprise behaviour model, and integration capability level. A refined classification of production strategies under circular economy conditions has been formed across four classification features.
8. The proposed approach has been applied to 20 agricultural enterprises in the Lviv Region, with a detailed case study of KSP 'Hriada' illustrating the economic viability and strategic advantages of a circular economy-oriented production strategy.

The practical significance lies in the development of an applicable toolkit for production strategy formation and selection based on circular economy principles, relevant particularly for Ukrainian enterprises in the context of European integration and post-war recovery.

The study is subject to several limitations. The empirical application covers agricultural enterprises from one region, which limits the generalisation of the findings to other sectors and institutional contexts. In addition, the proposed models and indicators require further quantitative validation. Future research should therefore test the approach in different industries and countries, compare alternative methods of

assigning weights to circular effects and examine the long-term results of strategies selected using the proposed framework.

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STRATEGIC MANAGEMENT OF ENTERPRISES IN THE TRANSITION TO A REGENERATIVE ECONOMY

Oleksandr Maslak, Tetiana Maslak[8]

Streszczenie

Artykuł analizuje strategie zarządzania przedsiębiorstwami w kontekście globalnego przejścia do gospodarki regeneratywnej. W oparciu o przegląd literatury oraz analizę przypadków z sektorów produkcyjnego, rolno-spożywczego i usługowego autorka identyfikuje kluczowe wymiary strategicznego dostosowania organizacji do wymogów modelu regeneratywnego. Gospodarka regeneratywna, wykraczając poza paradygmat zrównoważonego rozwoju, zakłada aktywne odtwarzanie zasobów naturalnych, społecznych i ekonomicznych – co stawia przed przedsiębiorstwami fundamentalnie nowe wyzwania w zakresie projektowania łańcuchów wartości, zarządzania zasobami ludzkimi oraz systemów pomiaru wyników. Artykuł proponuje ramy strategiczne łączące teorię zasobową przedsiębiorstwa z zasadami ekonomii cyrkularnej i regeneratywnej. Wnioski wskazują na konieczność transformacji modeli biznesowych oraz systemów zarządzania strategicznego jako warunku konkurencyjności w warunkach rosnącej presji regulacyjnej i rynkowej na rzecz dekarbonizacji i regeneracji ekosystemów.

Słowa kluczowe: gospodarka regeneratywna, zarządzanie strategiczne, transformacja modelu biznesowego, ekonomia cyrkularna, zrównoważony rozwój, łańcuch wartości

Summary

The article examines enterprise management strategies in the context of the global transition to a regenerative economy. Drawing on a systematic literature review and case analysis from manufacturing, agri-food, and service sectors, the author identifies the key dimensions of strategic organisational adaptation to the requirements of the regenerative model. The regenerative economy, extending beyond the sustainability paradigm, implies the active restoration of natural, social, and economic resources – posing fundamentally new challenges for enterprises in the design of value chains, human resource management, and performance measurement systems. The article proposes a strategic framework integrating resource-based theory with the principles of circular and regenerative economics. The conclusions indicate the necessity of transforming business models and strategic management systems as a prerequisite for competitiveness under conditions of increasing regulatory and market pressure toward decarbonisation and ecosystem regeneration.

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Keywords: regenerative economy, strategic management, business model transformation, circular economy, sustainable development, value chain

JEL: M21, Q01, Q56, L21

Introduction

The global economic system is undergoing a structural transition that extends well beyond the incremental adjustments associated with corporate sustainability programmes or environmental compliance frameworks. The concept of the regenerative economy – understood as an economic model that does not merely minimise harm to natural and social systems but actively restores and enhances them – has gained significant traction in academic, policy, and business communities over the past decade [Fullerton 2015: 12]. Unlike the circular economy, which focuses primarily on closing material loops and eliminating waste, the regenerative model embraces a systemic, living-systems perspective that treats enterprises as agents of ecological and social renewal rather than extraction [Mang and Reed 2012: 23].

For enterprises, this transition represents both a strategic imperative and a source of competitive opportunity. The escalating pressures of climate change, biodiversity loss, and social inequality are reshaping the regulatory and market landscape in ways that render conventional strategic approaches increasingly inadequate. The European Union's Green Deal, the Corporate Sustainability Reporting Directive (CSRD), and the emerging carbon border adjustment mechanism collectively signal a regulatory trajectory in which regenerative practices will shift from voluntary differentiators to mandatory baseline requirements [European Commission 2023: 5]. Concurrently, investor preferences, consumer behaviour, and talent attraction dynamics are amplifying the market incentives for strategic regenerativity.

Despite this significance, the academic literature on strategic management has been slow to integrate the regenerative economy perspective. Existing frameworks – including Porter's competitive strategy typology, the resource-based view, and dynamic capabilities theory – were developed in a context that largely treated the natural environment as an exogenous constraint rather than an endogenous strategic variable [Hart 1995: 986]. The emerging literature on natural capital, ecological economics, and biomimicry offers important conceptual resources but has not yet been synthesised into a coherent strategic management framework applicable to practising organisations.

This article addresses this gap through three objectives. First, to define the regenerative economy as a distinct economic paradigm and identify its implications for enterprise strategy. Second, to develop a strategic framework integrating resource-based theory with regenerative and circular economics principles. Third, to examine the practical dimensions of strategic transformation required for enterprises

transitioning toward regenerative models, drawing on illustrative sectoral cases. The article is structured as follows: Section 1 reviews the theoretical foundations of the regenerative economy and its relationship to adjacent paradigms. Section 2 develops the proposed strategic framework. Section 3 analyses sectoral transformation pathways. Section 4 addresses implementation challenges and enablers. Conclusions summarise the findings and propose directions for future research.

1. The Regenerative Economy: Conceptual Foundations and Strategic Implications

The theoretical genealogy of the regenerative economy draws on several distinct intellectual traditions. Ecological economics, pioneered by Daly [1977] and further developed by Costanza et al. [1997: 253], established the foundational critique of growth-centric economic models by demonstrating that natural capital – the stock of natural resources and ecosystems that generates flows of services essential to human welfare – is not substitutable by manufactured capital beyond critical thresholds. This insight, while widely acknowledged in environmental economics, has been insufficiently integrated into mainstream strategic management theory.

The concept of regenerative design, developed by Mang and Reed [2012: 24] drawing on the work of Mollison and Holmgren in permaculture, introduced the notion that human systems can be designed to co-evolve with living systems rather than extracting from them. Applied to economic organisation, this implies enterprises that function as participants in, rather than parasites upon, the ecological and social systems within which they operate. Regenerative enterprises do not merely reduce their negative externalities but generate positive ones: rebuilding soil health, sequestering carbon, restoring biodiversity, strengthening community social capital, and regenerating human capabilities [Wahl 2016: 41].

The regenerative economy is meaningfully distinct from the circular economy, with which it is often conflated. The circular economy, as conceptualised by the Ellen MacArthur Foundation [2013: 7] and operationalised in EU policy frameworks, focuses on technical and biological cycles that maintain material value through reuse, repair, remanufacturing, and recycling. While circular principles are necessary components of a regenerative system, they are not sufficient: a circular economy could in principle be fully achieved without any net positive contribution to ecological restoration [Braungart and McDonough 2002: 42]. The regenerative economy adds the dimension of systemic healing: the active restoration of degraded systems to states of greater vitality, resilience, and generative capacity.

For strategic management, the regenerative economy paradigm implies a fundamental reconceptualisation of the purpose of the enterprise. The Friedman doctrine – that the social responsibility of business is to increase its profits [Friedman 1970: 33] – has already been substantially challenged by stakeholder theory [Freeman 1984] and subsequent developments including the Business Roundtable's 2019

Statement on the Purpose of a Corporation. The regenerative paradigm extends this challenge by redefining value creation to encompass natural capital maintenance and enhancement as a core strategic objective, not a constraint or externality [Elkington 2018: 4].

2. A Strategic Framework for Regenerative Enterprise Management

The resource-based view (RBV) of the firm, originating with Penrose [1959] and systematised by Barney [1991: 101], holds that sustained competitive advantage derives from resources and capabilities that are valuable, rare, inimitable, and non-substitutable. While the RBV has been criticised for its static character and neglect of dynamic capabilities [Teece, Pisano and Shuen 1997: 516], it provides a useful foundation for integrating regenerative principles into strategic thinking. Specifically, the regenerative economy extends the relevant resource base to include natural capital – soils, water, biodiversity, atmospheric stability – as strategic assets whose degradation represents a form of capital destruction that ultimately undermines long-run competitive position.

Building on this foundation, we propose a strategic framework for regenerative enterprise management organised around four interconnected dimensions: value architecture, resource stewardship, organisational capabilities, and measurement systems.

The value architecture dimension concerns the redesign of business models and value chains to generate regenerative rather than extractive value flows. This requires enterprises to map their dependencies on and impacts upon natural and social capital, identify opportunities to close loops and restore degraded assets within their value chains, and redesign products and services that create value by enhancing rather than depleting the systems they interact with [Porter and Kramer 2011: 65]. The concept of "value through restoration" – capturing competitive advantage through the active regeneration of common resources – represents a strategic logic that is distinctive to the regenerative paradigm and has no direct analogue in conventional competitive strategy frameworks.

The resource stewardship dimension addresses how enterprises manage their dependencies on natural and human capital over time. Regenerative resource stewardship implies a shift from asset exploitation to asset cultivation: managing soils, watersheds, ecosystems, and communities as productive capitals that require investment to maintain their generative capacity [Fullerton 2015: 28]. For enterprises in agriculture, food, forestry, and extractive industries, this represents a fundamental transformation of operational logic. For service and manufacturing enterprises, it implies attention to upstream supply chain practices, built environment design, and community investment as strategic rather than philanthropic activities.

The organisational capabilities dimension identifies the specific competencies required to execute a regenerative strategy. These include ecological literacy (the

ability to understand and apply living-systems thinking to business decisions), systems design capabilities (the ability to map and redesign complex value chain interactions), stakeholder integration skills (the ability to co-create value with communities, suppliers, and ecological systems), and adaptive management capacities (the ability to learn and adjust strategies in response to complex system feedback) [Wahl 2016: 112]. These capabilities are largely absent from conventional strategic management curricula and represent a significant human capital development challenge for organisations pursuing regenerative transformation.

The measurement systems dimension addresses the critical challenge of quantifying regenerative value creation in ways that are credible, comparable, and decision-relevant. The limitations of conventional financial accounting for capturing natural and social capital dynamics are well-documented [Costanza et al. 1997: 260]. Emerging frameworks including the Natural Capital Protocol, the Impact-Weighted Accounts Initiative, and the EU's forthcoming Nature Restoration Law metrics provide partial solutions but have not yet converged on a standardised approach adequate to the full scope of regenerative value creation. Enterprises pioneering regenerative strategies face a measurement frontier challenge that simultaneously represents a source of first-mover advantage (through proprietary valuation methodologies) and a credibility risk (through greenwashing accusations in the absence of verified metrics).

3. Sectoral Transformation Pathways: Evidence from Agri-Food, Manufacturing, and Services

The practical manifestation of regenerative enterprise strategy varies substantially across sectors, reflecting differences in natural capital dependencies, regulatory exposure, consumer visibility, and technological feasibility. This section examines transformation pathways in three illustrative sectors: agri-food, manufacturing, and professional services.

The agri-food sector offers the most mature and institutionally developed examples of regenerative enterprise strategy. Regenerative agriculture – defined as a set of farming practices that rebuild soil organic matter, restore biodiversity, improve water cycles, and sequester carbon while maintaining or improving productivity [LaCanne and Lundgren 2018] – has been adopted by a growing number of food companies as a supply chain strategy. Unilever, Danone, and General Mills have each announced large-scale regenerative agriculture programmes covering hundreds of thousands of hectares, driven by a combination of supply chain resilience objectives, consumer brand positioning, and regulatory anticipation [Regeneration International 2021]. The strategic logic is that investment in soil health and biodiversity in supplier farms reduces medium-term input cost volatility, enhances product quality differentiation, and builds ahead of mandatory sustainability due diligence requirements in the EU supply chain.

In the manufacturing sector, the transition toward regenerative models is most advanced in industries with high material intensity and significant circular economy infrastructure. Interface, the global carpet tile manufacturer, offers a frequently cited case of strategic regenerative transformation: its Mission Zero programme (1994–2020) achieved the elimination of direct environmental harm from operations, while its subsequent Climate Take Back initiative extends the strategy to active carbon sequestration and biodiversity restoration [Interface 2022]. The competitive implications of Interface's regenerative strategy include premium pricing in commercial markets where environmental credentials are a procurement criterion, talent attraction advantages in knowledge-intensive design functions, and regulatory preparedness that reduces compliance cost uncertainty. Interface's case demonstrates that regenerative strategy can be pursued iteratively, with each phase building the organisational capabilities and technological infrastructure required for the next.

In the professional services sector, regenerative enterprise strategy manifests primarily through the design of services, advice, and built environments that enhance rather than deplete the systems they affect. Architecture and urban planning firms such as HOK and Perkins&Will have developed regenerative design methodologies that apply living-systems principles to building and neighbourhood design, targeting net-positive outcomes for energy, water, biodiversity, and human wellbeing [Mang and Haggard 2012: 34]. Management consultancies are increasingly developing regenerative economy practice areas, reflecting client demand for strategic guidance on the transition. The competitive dynamics of this emerging professional services segment are characterised by early-mover differentiation, significant methodological IP development, and a growing premium for practitioners combining deep domain expertise with systemic ecological literacy.

4. Implementation Challenges and Strategic Enablers

The transition to regenerative enterprise management faces a set of structural implementation challenges that are common across sectors and organisational types. Understanding these challenges – and the strategic enablers that can mitigate them – is essential for organisations developing regenerative transformation roadmaps.

The most fundamental challenge is the temporal misalignment between regenerative investment horizons and conventional financial planning cycles. Soil restoration, ecosystem regeneration, and community social capital development typically operate on timescales of five to twenty years, while financial markets and corporate planning cycles operate primarily on horizons of one to three years. This misalignment creates a structural underinvestment in regenerative activities from a purely financial perspective [Fullerton 2015: 45]. Organisations addressing this challenge have employed a variety of mechanisms including patient capital structures (impact bonds, blended finance instruments, long-term institutional investor partnerships), natural capital accounting practices that make regenerative investments

visible on balance sheets, and narrative strategy communication that aligns investor expectations with long-term value creation logic.

A second challenge concerns the distribution of regenerative value across supply chains. Many of the most impactful regenerative investments – in soil health, watershed restoration, community resilience – are made by upstream suppliers (farmers, raw material processors, community organisations) while a disproportionate share of the commercial value accrues to downstream branded enterprises. This distributional asymmetry creates incentive misalignments that constrain the pace and scale of supply chain regeneration [Porter and Kramer 2011: 72]. Enterprises addressing this challenge are experimenting with novel supply chain financing mechanisms, long-term supplier contracts with regenerative performance bonuses, and co-investment models in which downstream enterprises share the financial risk of upstream regenerative transition.

Governance and leadership represent a third critical implementation dimension. Regenerative strategy requires board-level recognition of natural and social capital as strategic assets, integration of ecological and social metrics into executive performance measurement, and willingness to accept short-term financial underperformance in exchange for long-run regenerative value creation [Eccles and Serafeim 2013: 51]. The evidence from corporate governance research suggests that board composition – specifically the presence of directors with ecological literacy, systems thinking capabilities, and long-term institutional investor alignment – is a significant predictor of regenerative strategy adoption [Flammer and Bansal 2017: 1810].

Regulatory and policy frameworks constitute both a challenge and a significant strategic enabler. The EU's Green Deal legislative package, including the CSRD, the EU Taxonomy for Sustainable Activities, and the proposed Nature Restoration Law, is creating a mandatory compliance architecture that will progressively reward regenerative enterprise practices and penalise extractive ones. For enterprises with the strategic foresight to position ahead of this regulatory trajectory, the transition represents a competitive advantage opportunity. For those that delay, the combination of compliance costs, stranded asset risk, and reputational damage associated with lagging performance on mandatory sustainability metrics will represent a growing strategic liability [European Commission 2023: 11].

Conclusion

This article has examined the strategic management challenges and opportunities associated with the enterprise transition to a regenerative economy. The analysis identifies the regenerative economy as a distinct economic paradigm that extends beyond sustainability and circularity to encompass the active restoration of natural, social, and economic systems – and demonstrates that this paradigm poses fundamental challenges to conventional strategic management frameworks.

The proposed four-dimensional strategic framework – encompassing value architecture, resource stewardship, organisational capabilities, and measurement systems – provides a structured approach to regenerative strategy development that integrates resource-based theory with regenerative economics principles. Sectoral analysis demonstrates that regenerative enterprise strategies are already commercially viable in agri-food, manufacturing, and professional services contexts, generating competitive advantages through supply chain resilience, brand differentiation, talent attraction, and regulatory preparedness.

Three principal conclusions emerge for theory and practice. First, regenerative enterprise strategy requires a fundamental reconceptualisation of value creation that treats natural and social capital restoration as a core strategic objective rather than a constraint. Second, the temporal and distributional misalignments inherent in regenerative investment require novel governance, financing, and supply chain coordination mechanisms that conventional strategic management frameworks do not adequately address. Third, the accelerating regulatory trajectory of the EU's Green Deal legislative package is converting regenerative strategy from a voluntary differentiator to a competitive necessity, creating first-mover advantages for enterprises that develop regenerative capabilities ahead of mandatory requirements.

The limitations of this analysis include the relatively limited availability of rigorous longitudinal evidence on the financial performance effects of regenerative strategies, the sector-specific character of the case evidence reviewed, and the rapidly evolving regulatory and technological context that renders any framework subject to revision. Future research should prioritise quantitative assessment of regenerative strategy performance effects across industries, development of standardised natural capital accounting methodologies applicable to enterprise strategy, and comparative analysis of the organisational capabilities profiles associated with successful regenerative transformation.

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BEHAVIORAL DETERMINANTS OF MARKET CONCENTRATION AND COMPETITION IN THE ELECTRIC VEHICLE MARKET: EVIDENCE FROM TÜRKİYE

***Murat Korkmaz*[9], *Kıymet Yavuzaslan*[10]**

Streszczenie
Gwałtowny rozwój rynków pojazdów elektrycznych (EV) zmienił zachowania konsumentów i dynamikę rynku konkurencyjnego. Rynki EV charakteryzują się niepewnością technologiczną, zależnością od infrastruktury i silnym wpływem zachowań na decyzje zakupowe. Porównanie adopcji pojazdów elektrycznych w Unii Europejskiej i Turcji ujawnia różne przyczyny. Nasze wyniki pokazują, że adopcji pojazdów elektrycznych nie można wyjaśnić wyłącznie postępem technologicznym lub świadomością ekologiczną; istotną rolę odgrywa również behawioralna rola Tureckiej Grupy Joint Venture (TOGG) jako krajowego wzorca technologicznego, wpływającego na zaufanie konsumentów w procesie transformacji rynku w Turcji.
Słowa kluczowe: Pojazdy Elektryczne, Ekonomia Behawioralna, Zachowania Konsumentów, TOGG

Summary
The rapid expansion of electric vehicle (EV) markets has transformed consumer behavior and competitive market dynamics. The EV markets are characterized by technological uncertainty, infrastructure dependency, and strong behavioral influences on purchasing decisions. Comparing EV adoption in the European Union and Türkiye reveals different reasons. Our results show that the EV adoption cannot be explained solely by technological advancement or environmental awareness; rather, the behavioral role of the Turkish Automobile Joint Venture Group (TOGG) as a domestic technological benchmark influencing consumer confidence during the market transition process in Türkiye is also significant.
Keywords: Electric Vehicles, Behavioral Economics, Consumer Behavior, TOGG

JEL: D91, L11, L62.

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Introduction

The global automotive industry has entered a profound transformation process shaped by electrification, digitalization, environmental concerns, and changing consumer preferences. For more than a century, internal combustion engine [ICE] vehicles dominated transportation systems due to their relatively low production costs, high energy density, and extensive fuel infrastructure. However, increasing environmental pressures, rising carbon emissions, and international climate policies have accelerated the transition toward battery electric vehicles [BEVs] as a central component of sustainable mobility strategies [European Parliament and Council of the European Union, 2019; IEA, 2023].

Unlike conventional automobiles, electric vehicles are not evaluated solely as transportation goods. EVs represent technologically intensive durable consumption goods whose demand structure is shaped by long-term expectations, infrastructure accessibility, operating costs, technological reliability, and behavioral consumer perceptions [Train, 2009; Varian, 2014]. In this respect, the transformation of the automotive industry involves not only technological and industrial change but also a significant behavioral transformation affecting consumer decision-making processes.

The growing importance of behavioral factors in EV markets has attracted increasing attention within the literature. Consumers frequently evaluate electric vehicles under conditions of uncertainty regarding charging accessibility, battery durability, resale value, and future technological developments. Therefore, purchasing decisions are influenced not only by income levels, prices, and policy incentives but also by psychological and behavioral determinants such as range anxiety, risk perception, trust mechanisms, and social influence [Axsen and Kurani, 2013; Rezvani, Jansson and Bodin, 2015]. In emerging EV markets, where information asymmetry and technological uncertainty are relatively higher, these behavioral tendencies may play an even stronger role in shaping market outcomes.

At the same time, the expansion of electric vehicle markets has introduced new dynamics into competition and market concentration structures within the automotive industry. Traditional competition theories generally explain market concentration through production capacity, technological efficiency, economies of scale, and entry barriers [Porter, 1980; Tirole, 1988]. However, EV markets differ from conventional automotive markets because consumer trust and behavioral expectations increasingly influence firm visibility and market performance. Under uncertainty, consumers may prefer highly recognized and trusted brands, which can indirectly strengthen the market positions of dominant firms.

Türkiye provides an important case for analyzing these dynamics. The Turkish EV market has expanded rapidly in recent years, particularly following increasing fuel prices, supportive tax policies, and the emergence of TOGG as a domestic EV

producer. Beyond its industrial role, TOGG has also functioned as a behavioral reference point associated with national technological identity, domestic production capability, and institutional trust. In this context, consumer preferences within the Turkish EV market appear to be shaped not only by economic considerations but also by behavioral perceptions regarding technological reliability and uncertainty.

In addition, the Turkish EV market differs from mature European markets in terms of energy price sensitivity and consumer expectations. While EV adoption in many European Union countries increasingly reflects a structurally institutionalized and sustainability-oriented transition process, EV demand in Türkiye appears to be more closely associated with inflationary pressures, fuel price volatility, and household cost sensitivity. This distinction highlights the importance of analyzing EV markets not only through technological or environmental perspectives but also within the broader framework of behavioral economics and market dynamics. The first section discusses consumer preference theory and durable goods literature in order to establish the theoretical foundations of the EV demand. The second section examines the role of behavioral economics in explaining the EV adoption decisions, focusing on concepts such as range anxiety, risk perception, and trust mechanisms. The third section analyzes the behavioral dynamics of the Turkish EV market through a comparative evaluation involving Türkiye and the European Union, with particular emphasis on fuel price sensitivity, consumer expectations, and the role of TOGG within the market transformation process. Finally, the conclusion section summarizes the main findings and discusses policy implications regarding sustainable competition and market development in emerging EV markets.

1. Consumer Preference Theory and Durable Goods

Consumer preference theory constitutes one of the fundamental theoretical approaches used to explain purchasing decisions in automobile markets. Within the framework of neoclassical consumer theory, individuals are assumed to behave rationally and maximize utility under budget constraints [Varian, 2014]. Consumers allocate their income among alternative goods according to relative prices, expected utility, and personal preferences. However, the demand structure of automobiles differs significantly from ordinary consumption goods because vehicles are generally classified as durable consumption goods providing utility over a long period of time [Train, 2009].

Durable goods are characterized by high purchasing costs, long usage periods, and intertemporal decision-making processes. Unlike non-durable products consumed immediately, automobiles generate a continuous flow of utility throughout their economic lifetime [Deaton and Muellbauer, 1980]. Therefore, consumers evaluate not only current purchasing costs but also future operating expenses, maintenance costs,

financing conditions, depreciation, and resale value expectations when making purchasing decisions [Train, 2009].

This framework becomes even more important in electric vehicle markets. Electric vehicles are not evaluated solely as transportation products; they are also perceived as technological investment goods associated with uncertainty regarding battery durability, charging infrastructure, technological obsolescence, and long-term operational performance [Sierzchula et al., 2014]. Consequently, EV consumers frequently make purchasing decisions by considering both present economic conditions and future technological expectations simultaneously.

In the literature, this long-term evaluation process is generally conceptualized through the Total Cost of Ownership [TCO] approach. The TCO perspective suggests that consumers compare not only initial purchasing prices but also lifetime operating costs, including electricity expenses, maintenance requirements, taxation, insurance, and resale value [Sierzchula et al., 2014]. Since electric vehicles generally involve higher initial purchasing costs but lower operating expenses compared to internal combustion engine vehicles, TCO calculations play a critical role in EV adoption decisions.

Expectations also constitute a central component of durable goods demand. Consumers frequently postpone purchasing decisions if they expect future price reductions, technological improvements, or more advanced product alternatives [Adda and Cooper, 2000]. This dynamic is particularly visible in electric vehicle markets due to rapid technological developments in battery systems, charging technologies, and software integration. As a result, EV demand structures tend to be more expectation-oriented and uncertainty-sensitive than conventional automobile markets.

Another important dimension concerns energy prices and financing conditions. Rising fuel prices may increase the relative attractiveness of electric vehicles by strengthening their long-term operating cost advantages [IEA, 2023]. Similarly, interest rates and credit conditions significantly influence automobile demand because vehicles are generally purchased through long-term financing mechanisms [Train, 2009]. In emerging markets characterized by inflationary pressures and exchange rate volatility, these macroeconomic variables may play an even stronger role in shaping EV demand patterns.

2. Behavioral Economics and The EV Adoption

Traditional consumer theory assumes that individuals make rational decisions by maximizing utility under complete information conditions. However, behavioral economics challenges this assumption by arguing that consumers frequently exhibit bounded rationality, cognitive biases, and uncertainty-sensitive decision-making patterns [Kahneman and Tversky, 1979]. These behavioral tendencies become

particularly important in markets characterized by technological complexity and future uncertainty, such as electric vehicle markets. Unlike conventional automobiles, electric vehicles are generally perceived as relatively new and technologically evolving products. Consumers frequently lack complete information regarding battery durability, charging accessibility, long-term maintenance costs, software reliability, and future resale value. Under such conditions, purchasing decisions are shaped not only by objective economic calculations but also by psychological perceptions and subjective expectations [Rezvani, Jansson and Bodin, 2015].

One of the most significant behavioral barriers affecting EV adoption is range anxiety. Range anxiety refers to consumers fear that battery capacity may be insufficient to complete a trip or access charging facilities when needed [Egbue and Long, 2012]. Although technological improvements have significantly increased driving ranges in recent years, consumer perceptions often remain influenced by uncertainty rather than actual technical performance. This demonstrates that behavioral responses to perceived risks may differ from purely rational evaluations.

Risk aversion also plays an important role in EV adoption decisions. According to prospect theory, consumers tend to weigh potential losses more heavily than equivalent gains [Kahneman and Tversky, 1979]. In the context of electric vehicles, uncertainty regarding battery replacement costs, technological obsolescence, charging infrastructure, and resale value may increase consumers perceived risks and reduce willingness to adopt new technologies. Consequently, many consumers prefer delaying purchasing decisions until technological uncertainty decreases. Another important behavioral factor concerns trust mechanisms. Consumers operating under incomplete information conditions often rely on visible and trusted brands when evaluating technologically complex products [Axsen and Kurani, 2013]. Brand reputation, institutional credibility, and perceived technological reliability may therefore influence EV adoption independently from objective product characteristics. This tendency becomes particularly important in emerging markets where technological uncertainty and information asymmetry are relatively stronger.

Social influence and social norms also contribute significantly to EV adoption behavior. Rogers diffusion of innovation theory suggests that individuals frequently observe the experiences and preferences of others before adopting new technologies [Rogers, 2003]. In EV markets, consumer attitudes are shaped not only by individual preferences but also by peer influence, public visibility, media representation, and environmental awareness. Early adopters may therefore play an important role in accelerating technology diffusion and shaping broader market perceptions.

Behavioral economics literature further emphasizes that consumers frequently focus disproportionately on initial purchasing prices while underestimating long-term operational advantages [Allcott and Wozny, 2014]. Although electric vehicles may provide lower energy and maintenance costs over time, consumers often evaluate EV

affordability primarily through initial acquisition costs. This behavioral bias may slow EV adoption despite potential long-term economic benefits.

In this respect, electric vehicle markets should not be evaluated solely through traditional demand theory or technological performance indicators. EV adoption represents a multidimensional process shaped simultaneously by economic rationality, psychological expectations, social influence, and uncertainty perception. Therefore, behavioral economics provides an essential analytical framework for understanding both consumer preferences and broader market dynamics within the electric vehicle transition process.

3. The EV Market Dynamics in Türkiye: A Behavioral Approach

The rapid expansion of electric vehicle markets has introduced new competitive dynamics within the automotive industry. Unlike conventional automobile markets, EV markets are characterized by technological uncertainty, infrastructure dependence, and rapidly evolving consumer expectations. Under such conditions, behavioral factors increasingly influence purchasing decisions and market structures simultaneously. One of the most important behavioral determinants shaping EV market concentration is risk perception. Consumers frequently evaluate electric vehicles under uncertainty regarding charging accessibility, battery durability, long-term maintenance costs, and future technological developments. In emerging EV markets such as Türkiye, these uncertainties become more visible due to relatively recent infrastructure expansion and limited long-term consumer experience with EV technologies. As a result, consumers often demonstrate higher levels of uncertainty avoidance when making EV purchasing decisions.

Range anxiety remains another major psychological barrier affecting EV adoption behavior. Although charging infrastructure investments have expanded significantly in recent years, many consumers continue to perceive electric vehicles as technologically restrictive compared to conventional internal combustion engine vehicles [Egbue and Long, 2012]. Behavioral responses to perceived charging limitations frequently exceed actual technical constraints, demonstrating the importance of psychological expectations within EV markets. Under such uncertainty, consumers generally prefer brands associated with stronger technological reliability and institutional trust.

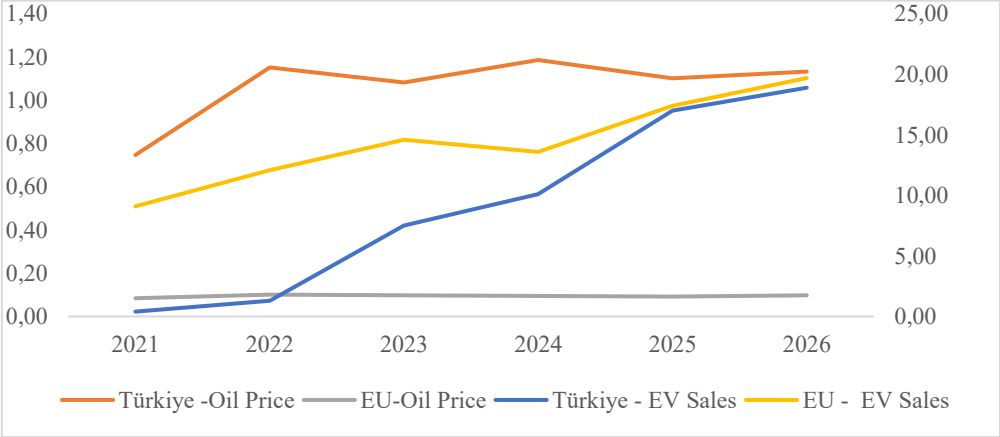
Trust mechanisms therefore play a central role in shaping competitive dynamics within the Turkish EV market. Consumers operating under incomplete information conditions tend to rely on visible and trusted brands in order to reduce perceived risks [Axsen and Kurani, 2013]. This tendency becomes particularly important during early technological transition periods when consumers lack sufficient long-term market experience. Consequently, firms capable of generating stronger perceptions of

reliability, technological competence, and institutional credibility may gain behavioral advantages independent of traditional price competition.

The emergence of TOGG illustrates this process clearly within the Turkish EV market. Beyond functioning as a domestic automobile producer, TOGG also represents a symbolic technological project associated with national production capability, industrial modernization, and state-supported technological transformation. In this context, many consumers perceive TOGG not only as a transportation product but also as a trusted domestic technological alternative within an uncertain market environment. Such behavioral perceptions increased the visibility of TOGG during the rapid expansion phase of the Turkish EV market. However, market concentration dynamics in emerging EV markets cannot be explained solely through brand visibility or behavioral trust mechanisms. During the same period, the Turkish EV market also experienced rapid demand growth, increasing product diversity, and the entry of new international EV producers. Therefore, expanding market size partially balanced concentration tendencies despite the behavioral advantages of highly visible firms. This suggests that behavioral effects may influence market concentration gradually rather than generating immediate structural dominance.

Socio-economic conditions further strengthen the behavioral dimensions of EV adoption in Türkiye. Rising fuel prices, inflationary pressures, and transportation cost concerns significantly increased consumer interest in electric vehicles after 2022. In contrast to many mature European EV markets, Turkish consumers increasingly evaluate EVs as economic protection mechanisms against volatile fuel expenditures and long-term transportation costs. Consequently, EV demand in Türkiye appears to be more strongly associated with economic uncertainty and household budget expectations.

Graph 1. Oil Prices and EV Sales: Türkiye and the European Union [2021–2026]



Source: Prepared by the authors based on Energy Market Regulatory Authority (EPDK), Automotive Distributors and Mobility Association (ODMD), European Environment Agency (EEA) and European Commission.

Graph 1 demonstrates the comparative relationship between oil prices and EV sales in Türkiye and the European Union between 2021 and 2026. The figure indicates that EV sales in the European Union continued to increase relatively steadily despite fluctuations in oil prices, reflecting a more institutionally mature and infrastructure-supported transition process. In many European countries, EV adoption increasingly depends on environmental awareness, policy continuity, and long-term technological confidence rather than short-term economic volatility [IEA, 2023].

In contrast, the Turkish EV market reveals a more uncertainty-sensitive adoption structure. Particularly after 2023, increasing fuel prices coincided with rapid acceleration in EV sales, suggesting that Turkish consumers strongly associate EV adoption with transportation cost expectations and economic security concerns. This distinction demonstrates that behavioral determinants of EV adoption differ significantly between mature and emerging markets. Another important factor influencing EV market concentration concerns information asymmetry. Consumers frequently possess limited information regarding battery life, software systems, maintenance requirements, and long-term operational performance. Under such conditions, consumers often avoid unfamiliar brands and prefer firms with stronger visibility and perceived reliability. This behavioral tendency may indirectly strengthen dominant market players and create competitive disadvantages for new entrants.

Social influence and peer effects also contribute significantly to EV adoption patterns in Türkiye. Consumers frequently observe the experiences of relatives, social networks, and early adopters before purchasing technologically unfamiliar products [Rogers, 2003]. Public visibility, social media discussions, and increasing urban

exposure to EV technologies therefore shape broader consumer attitudes and purchasing behavior.

Conclusion

The global transition toward electric vehicles represents not only a technological and environmental transformation but also a significant behavioral transformation affecting consumer preferences and market structures. Unlike conventional automobile markets, EV markets are characterized by technological uncertainty, infrastructure dependence, and rapidly evolving consumer expectations. Therefore, understanding EV market dynamics requires integrating behavioral economics with traditional market and competition analysis.

The analysis further indicates that EV adoption patterns differ substantially between mature and emerging markets. In the European Union, EV adoption increasingly reflects a structurally institutionalized transition process supported by stable environmental policies, extensive charging infrastructure, and long-term consumer confidence. In contrast, EV demand in Türkiye appears to be more strongly associated with economic uncertainty, fuel price sensitivity, inflationary pressures, and transportation cost expectations. Another important conclusion concerns the relationship between energy prices and EV adoption behavior. The comparative findings suggest that rising fuel prices influence EV demand much more strongly in Türkiye than in mature European EV markets. This demonstrates that consumer motivations in emerging markets remain closely connected to economic expectations and household cost considerations rather than solely environmental awareness.

The study also demonstrates that trust-oriented consumer behavior plays an important role in shaping market visibility and competitive dynamics within emerging EV markets. In this respect, the emergence of TOGG represents not only an industrial development but also a behavioral reference point associated with domestic technological reliability and institutional confidence in Türkiye. However, rapidly expanding market size and increasing product diversity simultaneously limited the emergence of immediate concentration pressures despite the behavioral visibility advantages of dominant firms. Therefore, sustainable EV market development requires policies extending beyond traditional fiscal incentives. Reducing information asymmetry, strengthening charging infrastructure confidence, improving consumer trust, supporting market diversity, and increasing transparency regarding EV technologies are critical for establishing competitive and sustainable EV markets in the long term. Finally, the study contributes to the literature by integrating behavioral economics, consumer theory, and market dynamics into a unified analytical framework for understanding the transformation of electric vehicle markets. Future research may further develop this perspective through empirical analyses examining

the long-term interaction between behavioral consumer tendencies and market concentration dynamics in emerging EV markets.

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LEVERAGING FINTECH INNOVATION FOR PROACTIVE RISK MANAGEMENT – EU EXPERIENCE AND STRATEGIC DIRECTIONS FOR UKRAINE'S EUROPEAN INTEGRATION IN TIMES OF CHANGE

Myroslava Bublyk[11]

Streszczenie

Rozdział uzasadnia wykorzystanie innowacji FinTech i proaktywnego zarządzania ryzykiem opartego na doświadczeniach UE do integracji Ukrainy z europejską przestrzenią finansową. Przeanalizowano zmianę paradygmatu na algorytmiczne zarządzanie ryzykiem stymulowane "efektem brukselskim" i SupTech. Porównując wskaźniki klasyczne i cyfrowe (DESI), zidentyfikowano asymetryczną atrakcyjność inwestycyjną, wykazując, że gotowość technologiczna Ukrainy rekompensuje niestabilność makrofinansową. Zaproponowano kierunki adaptacji: wdrożenie unijnych regulacji (DORA, MiCA, PSD3) oraz rozwój programowalnej e-hrywny zsynchronizowanej z cyfrowym euro dla zapewnienia przejrzystej alokacji pomocy międzynarodowej i powojennej odporności.
Słowa kluczowe: FinTech, proaktywne zarządzanie ryzykiem, integracja europejska, odporność makrofinansowa, ramy regulacyjne, transformacja cyfrowa.

Summary

This chapter substantiates leveraging FinTech innovations and EU-based proactive risk management to facilitate Ukraine's integration into the European digital financial space. The study analyzes the shift to algorithmic risk management driven by the «Brussels effect» and SupTech. Comparing classic and digital indicators (DESI), it identifies asymmetric investment attractiveness, showing that Ukraine's technological readiness compensates for macro-financial instability. Strategic adaptation directions are proposed: implementing EU frameworks (DORA, MiCA, PSD3) and developing a programmable e-hryvnia synchronized with the Digital Euro to ensure transparent aid allocation and post-war resilience.
Key words: FinTech, proactive risk management, European integration, macro-financial resilience, regulatory frameworks, digital transformation.

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Introduction

The rapid acceleration of technological progress and the increasing availability of data analysis tools are transforming the global financial architecture. In an era of constant uncertainty and geopolitical upheaval, the transition from reactive to proactive risk management has become a critical requirement for national economic security. FinTech innovations, ranging from predictive analytics based on artificial intelligence to automated compliance protocols, are now essential for ensuring financial stability. For Ukraine, implementing these achievements is not just a technical challenge, but a strategic imperative to align its financial regulatory framework with EU standards, thereby contributing to sustainable European integration and strengthening the economy's resilience to global instability.

The object of the study is the process of transformation of financial and credit systems and risk management systems under the influence of FinTech innovations in the context of European integration.

The subject of the study is the mechanisms for implementing European experience in FinTech innovations (in particular, DORA, MiCA, PSD2/PSD3 regulations) into the financial system of Ukraine and approaches to proactive risk management.

The purpose of the study is to study the European experience in implementing FinTech innovations as a tool for proactive macrofinancial risk management, as well as to develop strategic directions for adapting the financial sector of Ukraine to the standards of the EU Single Digital Market.

Main tasks: 1) analyze the evolution of the European financial architecture and the role of FinTech in the transition to proactive risk management in the EU; 2) investigate the latest indicators of the competitiveness of financial systems and compare the positions of Ukraine and the EU; 3) assess the impact of European regulatory frameworks (DORA, MiCA, AI Act) on minimizing systemic risks; 4) develop a roadmap for the institutional and technological adaptation of the financial system of Ukraine to the requirements of the EU Single Digital Market.

1. Conceptual foundations of the transformation of financial and credit systems in the European digital space

In the context of economic globalization and the unprecedented development of digital technologies, understanding the essence of financial and credit systems requires an updated, transnational approach. The study of transformation processes in this area is based on several basic categories, among which the following seven concepts are key: financial and credit system, international financial integration, financial technologies (FinTech), cross-border capital movements, digital assets, international competitiveness of the financial sector, financial stability. To describe the theoretical basis of this study, let us clarify the most important of these terms. The

financial and credit system is a set of interconnected financial institutions, markets, instruments and regulatory mechanisms that ensure the mobilization, distribution and cross-border movement of free capital in the context of the global economy [Bublyk and Pikhniak 2025: 293]. International financial integration is the process of merging national financial markets into a single global space by removing barriers to capital movements, harmonizing regulatory norms and unifying financial instruments [Bublyk and Nashkerska 2025: 351]. FinTech or financial technology is an innovative industry that uses the latest technological solutions (artificial intelligence, blockchain, cloud computing) to improve, automate and expand access to financial services at the macro and micro levels [ECB 2023: 12]. The term "digital assets" also plays an important role, which includes cryptocurrencies, stablecoins and central bank digital currencies. In the modern dimension, they are considered not only as a means of payment, but also as a tool for transforming global liquidity [European Parliament 2023]. Cross-border capital movement today is determined by the speed of digital transactions and requires new approaches to financial stability – the system's ability to withstand not only macroeconomic shocks, but also global cyber threats [European Parliament 2022: 5].

Modern financial and credit systems do not operate in isolation; they are an organic part of the architecture of international economic relations. Their effectiveness is determined by the ability to accumulate global investments, minimize cross-border risks and ensure the continuity of settlements.

The relationships between them are implemented through a few mechanisms that can be grouped into areas: cross-border financing mechanisms, settlement and payment mechanisms, global risk management mechanisms (hedging) and regulatory and compliance mechanisms [FSB 2023: 15].

The systematization of these mechanisms and their features, which determine the vectors of Ukraine's integration into the European financial space (in particular, regarding joining the SEPA payment area and implementing European regulatory directives), is given in Table 1.

A feature of the functioning of modern financial systems is the deep integration of settlement, regulatory and innovation mechanisms. Unlike the market-spontaneous model of the USA, where the technological development of finance has historically been dictated by venture capital and technological giants (BigTech), the European Union has chosen the path of "regulatory innovation" (the so-called "Brussels effect"). The EU forms global standards through proactive legislation, which is reflected in the mechanisms listed in Table 1. For Ukraine, as a state that is in the process of European integration and needs effective tools for post-crisis recovery, the main task is to implement these European directives into national practice [Bublyk and Pikhniak 2025: 25].

Table 1. Mechanisms of functioning of financial and credit systems

Mechanism	Features of operation	EU Experience
Settlement and payment	Transborder payments through unified systems	SEPA and TARGET2. Provide instant payments in euros. Ukraine is already joining the SEPA zone
Regulatory and compliance	Unification of financial monitoring and cyber protection	DORA (Digital Operational Resilience Act). A single cybersecurity standard for the EU financial market
Innovative (Open Finance)	Open access to financial data via API	PSD2/PSD3 Directive. Creating a single European market for open finance

Source: compiled by the author based on [ECB, 2023; European Commission, 2023]

In the third decade of the 21st century, the development of financial and credit systems is determined by the symbiosis of macroeconomic turbulence and rapid technological evolution. Research into European experience confirms that those financial institutions that adapt to innovations in a rigid regulatory environment most quickly hold the leadership. A key macroeconomic trend is the European Central Bank's (ECB) shift to a "dear money" policy in response to inflationary shocks. As European banks can no longer rely on cheap liquidity, they are forced to optimize operating costs through digitalization. An additional and uniquely European challenge is the stringent requirements of ESG criteria (sustainable financing), which force banks to systematically review their loan portfolios in favor of socially and environmentally responsible projects [Bublyk 2025: 135]. In these conditions, the development of innovative mechanisms, particularly the concept of open banking (Open Finance), is becoming a powerful driver of transformation. Its essence lies in the use of API technologies. The implementation of the Payment Services Directive (PSD2, and now the transition to PSD3) in the EU has effectively destroyed the monopoly of traditional European banks on customer data. Technology companies have gained legal access to users' financial history, which has stimulated the powerful development of the neobank ecosystem (e.g. Revolut, N26) without harming systemic stability. Ukraine, actively implementing the law on payment services and preparing to join the Single Euro Payments Area (SEPA), is implementing these digital solutions on the way to the European financial space [European Commission 2023].

No less revolutionary is the transition to proactive risk management using artificial intelligence. The ECB and the European Securities and Markets Authority (ESMA) are actively implementing supervisory technologies (SupTech). Today, every cross-border transaction within the European payment system TARGET2 is checked for money laundering. The use of European RegTech solutions based on neural networks allows analyzing millions of transactions in milliseconds, revealing hidden behavioral

anomalies before risks arise. This radically reduces the costs of financial institutions for compliance and increases capital transparency [Matseliukh et al. 2025: 5].

The transformation of cross-border payments through digital assets and decentralized finance (DeFi) deserves special attention. Stablecoins (especially those pegged to the euro) allow for the bypassing of the traditional correspondent banking system, making settlements through distributed ledgers virtually instantaneously. To minimize the macroeconomic risks of this parallel infrastructure, the EU was the first in the world to introduce a comprehensive MiCA (Markets in Crypto-Assets) regulation. Together with the ECB's Digital Euro pilot project, this creates a reliable institutional perimeter. It is to these strict European rules that Ukrainian legislation in the field of virtual assets must inevitably adapt [European Parliament 2023: 42].

Ultimately, the flip side of total digitalization is the transformation of cybersecurity from a purely technical IT problem into a fundamental macroeconomic factor. The migration of core banking systems to cloud environments makes markets vulnerable. A breach of data center systems could trigger a liquidity crisis across the region. Therefore, the systemic response of Europe was the development of the DORA (Digital Operational Resilience Act) regulation, which establishes uniform standards for digital operational resilience. The protection of information financial systems is today equated with ensuring national security [Kondrat, Bublyk and Yaroshevych 2026: 256].

Thus, the competitiveness of the modern financial and credit system is determined not so much by the volume of its assets, but by its technological architecture and ability to organically integrate into the digital market. For Ukraine, it is this European model, which balances between innovations (through «regulatory sandboxes») and strict protection of consumer rights (through the DORA, MiCA, PSD3 regulations), that is the only and indisputable guideline for successful integration into the single EU financial space.

2. Competitiveness and investment attractiveness of financial systems in the context of the development of FinTech innovations

The traditional paradigm for assessing the international competitiveness and investment attractiveness of financial systems was formed in the era of the industrial economy, when the main criteria for success were the volume of accumulated capital, the physical presence of financial institutions and the stability of the national currency. Classical approaches to measuring these characteristics are based on macroeconomic aggregates and composite indices developed by leading international institutions. The fundamental indicator in this group remains the Global Competitiveness Index, calculated by the World Economic Forum, where the financial system is assessed through the prism of credit availability, bank reliability and stock exchange regulation. No less important is the Financial Development Index from the International

Monetary Fund, which focuses on the depth, accessibility and efficiency of financial institutions and markets. Investment attractiveness in the classical sense is most often reduced to the analysis of sovereign credit ratings from the big three agencies (Standard & Poor's, Moody's, Fitch), as well as the volume of foreign direct investment (FDI) and the level of stock market capitalization in relation to GDP. These indicators perfectly described the balance of power in the pre-digital era, clearly recording the historical leadership of traditional financial hubs due to their resource base. However, today the European Union is shifting the paradigm, forming a standardized digital market. In the context of deepening globalization and exponential development of FinTech innovations, classical metrics have begun to lose their exhaustiveness. Digitalization has led to the dematerialization of financial services: today the competitiveness of a bank or a country's financial system is determined not by the number of branches or the volume of gold reserves, but by the speed of transaction processing, the quality of open application programming interfaces (APIs) and the level of cyber resilience. This has led to the emergence of a completely new group of neo-indicators that measure the technological flexibility of financial systems. These new indicators include the Global FinTech Index (Global FinTech Index by Findexable), which assesses the startup ecosystem, the availability of regulatory sandboxes, and the volume of venture financing for innovations. Another critically important indicator for the European space is the Digital Economy and Society Index (DESI by the European Commission), which reflects the progress of EU member states in the digitalization of the economy and finance. This picture is complemented by the National Cybersecurity Index (NCSI), which measures the security of digital infrastructure and the ability to resist cross-border threats.

For a systematic understanding of the evolution of assessment criteria, classic indicators and the latest FinTech indicators are systematized in Table 2.

The inconsistency and depth of the impact of these new indicators is that they reveal the phenomenon of asymmetric competitiveness. In the classical paradigm, capital has always flowed to countries with the highest credit ratings (AAA), avoiding markets with high sovereign risks. However, in the paradigm of open banking and decentralized finance, we observe a different trend: technological capital (venture capital, developers, users) flows to where there is a favorable, flexible regulatory environment for testing artificial intelligence algorithms, even if this country has a low classical investment rating. The gap between the availability of traditional capital and the speed of innovation implementation becomes a key problem for conservative markets and at the same time opens a window of opportunity for developing economies.

A comparative analysis of the financial and credit systems of Ukraine, the USA and the EU by both groups of indicators, presented in Table 3, clearly illustrates this paradox.

Table 2. Classic and modern indicators for assessing financial systems: global and European context

Indicator Group	Indicator / Index Name	Essence of measurement	Developer
Classical Macroeconomic Indicators	Financial Development Index (FDI)	Depth and accessibility of traditional banking services, volume of assets, capitalization of exchanges	IMF
	Sovereign Credit Rating	The ability of the state and its financial system to timely service external debt obligations	S&P, Moody's, Fitch
	Foreign Direct Investment (FDI inflows)	The volume of long-term capital attracted to the real and financial sectors of the economy.	UNCTAD, World Bank
Latest FinTech Indicators	Global FinTech Index (GFI)	The number of technology companies, the presence of innovation hubs, the volume of venture investments in FinTech.	Findexable
	Digital Economy and Society Index (DESI)	Measures the progress of EU member states in the digitalization of the economy and finance	European Commission
	Cybersecurity Index (NCSI / GCI)	The security of digital financial infrastructure, readiness to resist cross-border cyberattacks	eGA

Source: compiled by the author based on [IMF, 2023; European Commission, 2023; Findexable, 2022]

Analysis of the data in Table 3 confirms that although the USA has historically held the lead in terms of institutional capital, it is the European Union that is today the absolute world leader in standardization and safe integration of FinTech innovations into the traditional banking sector. Thanks to the PSD2/PSD3 directives and the MiCA regulation, the European regulatory system dictates the rules of the game at the global level, forming the so-called "Brussels effect". For Ukraine, the path to sustainability lies precisely through copying this European regulatory framework, which can compensate for its low classical credit ratings. At the same time, the situation with Ukraine is a unique precedent in international economic relations. Having objectively low investment attractiveness according to classical criteria (due to macroeconomic instability and the consequences of a long war), the domestic financial system demonstrates amazing stability and high competitiveness in the digital dimension. The high level of penetration of digital banking, the speed of cross-border transfers through integration with European payment systems (in particular, preparation for joining SEPA), and leading positions in the use of virtual assets form a new, non-traditional vector of investment attractiveness of Ukraine. For international FinTech companies, the Ukrainian market is becoming attractive as a platform for testing

advanced payment solutions in extreme conditions, which makes the technological factor the main driver of the future full-fledged financial integration of our state into the European economic space.

Table 3. Comparative assessment of investment attractiveness of financial systems: Ukraine, USA and EU

Indicator	**Ukraine**	**USA**	**EU**
Sovereign Credit Rating	High Risk / Speculative (CC/CCC)	Highest Investment Grade (AA+)	High investment grade (average AA/AAA for EU core)
Open Banking Maturity	In the implementation stage (Payment Services Law)	Fragmented (Private Market Initiatives)	Absolute leader (PSD2/PSD3 Directives, mandatory APIs)
Global FinTech Index Rank	In the Top 50	1st in the World	Strong regional hubs (Berlin, Paris, Amsterdam)
Crypto-assets regulation	In the process of development / adaptation	Fragmented (SEC and CFTC Conflicts)	Highly standardized (MiCA regulation implemented)
Digital Public Services	Very high (Diya ecosystem)	Average (Varies by State)	High (eIDAS, European digital wallet initiatives)

Source: [World Bank, 2023; European Commission, 2023; Findexable, 2022]

3. The role of FinTech innovations, artificial intelligence and digital assets in the modern global financial architecture

The modern global financial architecture, the fundamental contours of which were laid down by the Bretton Woods and Jamaica systems, is currently undergoing the most extensive transformation in the last half century. The very paradigm of international economic relations is changing: a transition from an institutional-centric model (where the main players were exclusively transnational banks and central governments) to a network-centric digital ecosystem. In this new reality, FinTech innovations, artificial intelligence and digital assets are no longer simply auxiliary tools for automating operational processes; they have become the supporting structures (base level) of global capital flows. Their synergy is fundamentally changing the speed of money circulation, global liquidity management mechanisms and the nature of systemic risks. For a conceptual understanding of the role of each of these technologies in building a new financial architecture, their key characteristics, macroeconomic benefits and hidden threats to the international economy are systematized in Table 4.

The analysis of the above data reveals several extremely deep and unobvious geoeconomic paradoxes that are fundamentally changing the balance of power in the world. The first paradox concerns the role of artificial intelligence in risk management. At the micro level, the implementation of artificial intelligence makes an individual transnational bank much more resilient, as neural networks are able to analyze thousands of nonlinear factors and reject risky cross-border loans. However, at the macro level, this creates unprecedented systemic risk. Since most leading financial institutions use similar data sets and optimization algorithms, the effect of "algorithmic herd behavior" arises. In the event of an unpredictable macroeconomic shock, thousands of AI-based systems around the world can simultaneously decide to withdraw capital from a certain region, for example, from emerging markets. This can provoke an instant and devastating liquidity crisis that cannot be stopped by traditional central bank tools, because the reaction speed of machines is measured in milliseconds.

Table 4. The role of innovative technologies in transforming the global financial architecture

Technology segment	**The nature of the impact on international finance**	**Macroeconomic benefits**	**Systemic risks (threats)**
FinTech (Open Banking, DeFi, API- platforms)	Disintermediation (elimination of classic intermediaries). Creation of cross-border settlement networks parallel to the traditional SWIFT system	Lower transaction costs; faster capital flows; financial inclusion for emerging markets	Fragmentation of global oversight; risk of systemic «shadow» banking, not controlled by central banks
AI and ML	Change of capital allocation algorithms. Transfer of macroeconomic forecasting, scoring and compliance (RegTech) functions to neural networks	Removing information asymmetry; instant detection of money laundering schemes; ultra-high market liquidity through algorithmic trading	Risk of «herd behavior» of algorithms (causing global flash crashes); loss of human control over credit cycles
Digital assets (Stablecoins, CBDC, tokenization)	Dematerialization of values. Transformation of the essence of fiat money through the issuance of digital currencies by central banks and private stablecoins	Ability to program money for specific purposes (smart contracts); instant cross-border clearing without correspondent banks	Risk of loss of monetary sovereignty by weak economies; total control of governments (via CBDC) over citizens' spending

Source: systematized by the author based on [BIS, 2023; ECB, 2023; FSB, 2023]

The second non-obvious phenomenon concerns the architecture of digital assets, in particular stablecoins, i.e. cryptocurrencies tied to the exchange rate of fiat money.

If previously digital assets developed in the "gray zone", relying mainly on unregulated stablecoins, today the European Union is fundamentally changing this architecture. The introduction of the MiCA regulation creates the world's first comprehensive legislation that transforms virtual assets from a speculation tool into a legal financing mechanism with strict requirements for issuers' reserves. This protects the European macro-region from systemic crises and forms a reliable legal perimeter, to which Ukrainian legislation is already actively adapting today. The third revolutionary element that is changing the architecture of international finance is the development of central bank digital currencies (CBDCs). Unlike decentralized blockchain projects, central bank digital currencies are a tool of absolute centralization. The launch of a digital euro, digital dollar, or digital hryvnia (e-hryvnia) fundamentally changes the transmission mechanism of monetary policy. Central banks are given the opportunity to directly issue money to the wallets of citizens and businesses, bypassing commercial banks. Moreover, thanks to smart contracts, this money can be "programmed": for example, to set its expiration date to stimulate immediate consumption during an economic recession, or to block its spending on imported goods to balance the balance of payments. This gives governments unprecedented power over the economy, but at the same time creates risks of fragmentation of the global financial system, as each state will build its own closed digital perimeter. In summary, it can be argued that for Ukraine, integration into this updated global financial architecture requires more than just mechanical copying of foreign banking applications. This requires building a strong sovereign institutional framework capable of harmonizing national regulation of artificial intelligence with the European regulation (AI Act), creating a secure legal regime for the circulation of stablecoins, and developing protective mechanisms against algorithmic capital outflows. Only under such conditions will technological transformation become a factor of resilience for our economy, and not a channel for importing global crises.

4. Recommendations for adapting the financial and credit system of Ukraine to international standards of sustainability and risk management

The integration of the financial and credit system of Ukraine into the European and global economic space in conditions of macroeconomic turbulence requires a fundamentally new approach to risk management. The classical paradigm of prudential supervision, which was based on the requirements of the Basel Committee (Basel III/IV) on maintaining capital adequacy and liquidity standards, turns out to be insufficient in the digital age. Today, financial stability (resilience) is determined not only by the volume of reserved funds, but also by the technological ability of the system to withstand nonlinear shocks: cross-border cyberattacks, instant liquidity

outflows through digital channels, and algorithmic failures. Taking into account the best practices of the European Central Bank (ECB) and the European Securities and Markets Authority (ESMA) in the field of regulatory technologies (RegTech), as well as new EU initiatives on digital security, the adaptation of the Ukrainian financial sector should take place through a deep implementation of FinTech tools directly into the risk management architecture at both the macro level (regulator) and the micro level (corporate sector).

For a systemic view of the developed proposals, the key adaptation tools, their international basis and expected economic effects are systematized in Table 5.

Table 5. Innovative tools for adapting the financial and credit system of Ukraine to European sustainability standards

Adaptation tool	**The essence of the risk management mechanism**	**Basic European standard**
Implementing SupTech (Supervisory AI Technologies)	Predictive analysis of reporting and transactions in real time to identify systemic risks	ECB and EBA (European Banking Authority) Experience with Algorithmic Supervision
Implementing Cyber Resilience	Transformation of IT security into a financial standard, stress tests of cloud providers	EU Regulation DORA (Digital Operational Resilience Act 2022/2554)
Regulating Tokenization and Smart Contracts	Use of blockchain protocols by the corporate sector in the legal field	EU Regulation MiCA (Markets in Crypto-Assets)
Programmable Digital Currency (CBDC)	Issue of digital currency with smart contract terms (control of targeted subsidies)	ECB's Digital Euro Project

Source: formulated by the author based on [ECB, 2023; European Parliament, 2022, 2023]

A deep analysis of the proposed recommendations reveals their non-obvious economic nature. First, we are talking about the introduction of supervisory technologies (SupTech) into the activities of the National Bank of Ukraine. Traditional banking supervision works with a time lag: the regulator receives reports for the past month, when the liquidity crisis in an individual bank could already have become irreversible. Using the experience of European supervisory authorities, which use SupTech tools based on artificial intelligence to analyze millions of transactions (such as the ECB's Athena system), will allow the NBU to change the paradigm from reactive to predictive. Algorithms can notice correlations that are imperceptible to humans – for example, how a change in the behavior of borrowers in the agricultural sector simultaneously affects the liquidity of several banks – and prevent a systemic collapse before it is reflected in traditional accounting balance sheets. This

fundamentally changes the level of trust of international partners in the Ukrainian financial system, since stability is ensured not only by currency interventions, but also by the mathematical accuracy of supervision.

No less important, although paradoxical at first glance, is the recommendation to implement the European DORA (Digital Operational Resilience Act) regulation. In classical economic theory, cybersecurity has always been considered a technical issue for IT departments. However, in the context of globalization, cyber risk has become a form of financial risk. A successful cross-border attack on a commercial bank's data center can paralyze the payment system of an entire country and lead to a panicky outflow of deposits, which will instantly destroy the capital adequacy ratio. Therefore, the implementation of DORA means that from now on, technological continuity is assessed as a financial asset. Banks will be forced to form reserves not only for non-performing loans (NPL), but also for the risks of stopping their digital services and cloud providers. For Ukraine, which is constantly under the sights of hybrid attacks, such institutionalization of cyber resilience is a fundamental condition for maintaining its sovereign rating and attracting European capital.

Descending from the macroeconomic level to the micro level, it is worth noting the revolutionary nature of the use of smart contracts and tokenized assets for corporate risk management. Traditional instruments for hedging currency or interest rate risks (forwards, options) are extremely expensive and inaccessible to the average Ukrainian business due to high bank fees and collateral requirements. The solution to this problem lies in the sphere of decentralized finance, but if they are introduced into the legal field through the standards of the European MiCA regulation. This will allow enterprises to significantly reduce transaction costs, protect working capital from exchange rate shocks and prove that FinTech innovations regulated by EU standards are able to provide a high level of financial stability even for small companies in an unstable economy.

Finally, a conceptual step for Ukraine to adapt to new realities should be the launch of a digital national currency (e-hryvnia) based on a programmable blockchain, the architecture of which should be conceptually synchronized with the ECB's Digital Euro project. The non-obvious macroeconomic effect of CBDC lies in the so-called structural de-risking of international aid. The main obstacle to the mass influx of foreign investors into Ukraine is the fear of misuse of funds. The programmability of digital money allows the terms of a smart contract to be built into the transaction structure itself. For example, tranches allocated by European donors for infrastructure restoration can be technologically programmed in such a way that they cannot be physically transferred to the accounts of offshore companies, converted into cash, or spent on non-target imported goods. Such cryptographic control over each unit of emission creates absolute transparency, which is valued much higher on international

markets than classic audit reports, and forms a reliable foundation for Ukraine's post-war reconstruction and European integration.

Conclusion

The study solves a pressing scientific problem regarding the theoretical and methodological justification of the adaptation of the financial and credit system of Ukraine to European sustainability standards based on FinTech innovations. In accordance with the tasks set, the following results were obtained:

First, the evolution of the European financial architecture was analyzed and it was proven that it is experiencing a paradigm shift - a transition from reactive supervision to proactive risk management. The key role in this process is played by the «Brussels effect» - the EU's ability to form global standards through proactive legislation (in particular, the PSD2/PSD3 and Open Banking directives), as well as the introduction of supervisory technologies (SupTech) based on artificial intelligence, which allows for the detection of systemic threats in real time.

Secondly, a comparative assessment of international competitiveness using the latest indicators allowed us to identify the phenomenon of asymmetric investment attractiveness. It has been established that classical macroeconomic metrics (such as sovereign credit ratings) lose their exhaustiveness in the digital age. At the same time, according to technological readiness indicators (digital banking penetration, digitalization of public services), the domestic financial system, even in conditions of macroeconomic turbulence, demonstrates high resilience, which creates a solid foundation for its organic integration into the EU Digital Single Market.

Third, the impact of the latest European regulatory frameworks on minimizing systemic risks has been assessed. It has been proven that the implementation of the DORA regulation is a critical necessity, as it transforms technological continuity and cybersecurity from a technical issue into a fundamental financial asset. In turn, the standardization of the crypto-asset market through the MiCA regulation paves the way for the legal use of smart contracts and tokenization for the corporate sector, allowing businesses to significantly reduce the cost of hedging risks.

Fourth, strategic vectors of Ukraine's institutional adaptation to EU requirements have been formed. To ensure macro-financial stability in the post-war recovery, the National Bank needs to move to predictive algorithmic supervision. A conceptual step should be the development of a digital national currency (e-hryvnia), architecturally synchronized with the European Digital Euro project. The programmability built into CBDC based on smart contracts will ensure absolute transparency and targeted control of the distribution of international aid, which is the main prerequisite for eliminating corruption risks and attracting large-scale European investment capital.

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ADOPTION OF AI IN THE SUPPLY CHAINS OF EUROPEAN MANUFACTURING COMPANIES – CLUSTER ANALYSIS AND DIMENSIONS OF DIGITIZATION

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Streszczenie
W artykule przeanalizowano Artykuł analizuje adopcję sztucznej inteligencji (AI) i technologii cyfrowych w łańcuchach dostaw 400 europejskich przedsiębiorstw produkcyjnych z Francji, Niemiec, Zjednoczonego Królestwa, Włoch i Hiszpanii. Zastosowano statystyki opisowe, korelację rang Spearmana, analizę składowych głównych (PCA) oraz analizę skupień metodą k-średnich. Poziom adopcji AI jest umiarkowany. PCA wyróżnia trzy wymiary: operacyjną AI, integrację z dostawcami oraz strategiczny nearshoring. Analiza skupień identyfikuje liderów cyfrowych (26%) i opóźnionych cyfrowo (74%). Silna korelacja (r = 0,575) między reakcją na COVID-19 a obecnym poziomem adopcji AI wskazuje, że pandemia trwale przyspieszyła cyfryzację. Małe firmy (poniżej 50 pracowników) są nieproporcjonalnie często liderami w wymiarze operacyjnej AI, natomiast przedsiębiorstwa brytyjskie osiągają istotnie niższe wyniki w tym obszarze.
Słowa kluczowe: sztuczna inteligencja, zarządzanie łańcuchem dostaw, cyfryzacja, analiza skupień, analiza składowych głównych, COVID-19, europejski przemysł produkcyjny

Summary
This article examines the adoption of artificial intelligence (AI) and digital technologies in the supply chains of 400 European manufacturing firms from France, Germany, the United Kingdom, Italy and Spain. Descriptive statistics, Spearman rank correlation, principal component analysis (PCA) and k-means clustering were applied. AI adoption is moderate across the examined areas. PCA identifies three dimensions: operational AI, supplier integration and strategic nearshoring. Cluster analysis reveals Digital Leaders (26%) and Digital Laggards (74%). A strong correlation (r = 0.575) between COVID-19 response and current AI adoption indicates that the pandemic acted as a lasting accelerator of digitalization. Small firms (fewer than 50 employees) are overrepresented among Digital Leaders in operational AI, while UK firms score significantly lower in this dimension.
Key words: artificial intelligence, supply chain management, digitalization, cluster analysis, principal component analysis, COVID-19, European manufacturing

JEL: F23, L23, O33, O52, C38

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Introduction

In recent years, global supply chains have experienced numerous serious disruptions. The COVID-19 pandemic exposed the weaknesses of the just-in-time model. The war in Ukraine hindered transport and access to raw materials. Additionally, geopolitical tensions between the United States and China prompted companies to rethink their sourcing strategies. As a result, manufacturing enterprises had to quickly adapt to new conditions.

One of the most important tools for this adaptation has been digitization. Artificial intelligence, automation, and systems enabling real-time supply chain monitoring have played an increasingly significant role. These technologies increase process transparency, facilitate responses to disruptions, and help reduce operational costs.

Despite growing interest in this topic, empirical knowledge remains limited. Most existing research is based on case studies or analyses conducted in single countries. There is still a lack of comparative studies covering several European countries at once. It is also unclear whether AI adoption is a single, coherent phenomenon or rather consists of several distinct dimensions developing independently.

This article aims to partially fill this gap. The study pursues three objectives. First, it assesses the level of AI and automation adoption in the supply chains of European manufacturing companies. Second, it examines whether the COVID-19 pandemic has had a lasting impact on the level of enterprise digitization. Third, it investigates whether AI adoption is homogeneous or a multidimensional phenomenon.

The analysis is based on primary data collected as part of the NCN Miniatura 8 grant (no. 625115). The sample includes 400 manufacturing companies from five Western European countries: France, Germany, the United Kingdom, Italy, and Spain. The data was collected through an online survey (CAWI). Four analytical methods were used in the study: descriptive statistics, analysis of correlations between thematic blocks, principal component analysis (PCA), and k-means cluster analysis.

The article consists of six parts. Section 2 presents the literature review and research hypotheses. Section 3 describes the data and methodology used. Section 4 presents the results of the analyses. Section 5 discusses their significance and implications. Section 6 contains conclusions and directions for further research.

The article makes three main contributions to the literature. First, it provides empirical data on AI adoption simultaneously in five European countries, which is still rare in this field of research. Second, it shows that AI adoption is not a single, homogeneous phenomenon, but rather encompasses three distinct dimensions. Third, it documents the lasting impact of the COVID-19 pandemic on the level of supply chain digitization.

1. Literature review

In the literature, artificial intelligence is increasingly rarely treated as a single tool. More and more often, it is described as a technology that affects many processes simultaneously. Walter [2023] demonstrates this using the example of manufacturing companies. AI supports demand planning, inventory management, transport optimization, and cooperation with suppliers. Thus, it is not just an addition to the existing system but becomes part of the decision-making process.

Similar conclusions are presented by Fosso Wamba i in. [2022]. In their literature review, they identify seven main areas of AI application in supply chains: demand forecasting, inventory management, supplier selection, transport, risk monitoring, customer service, and returns management. The authors emphasize that these areas can develop independently of each other. This means that AI implementation does not have to proceed uniformly across the whole organization.

The gradual nature of this process is also highlighted by Ivanov i Dolgui [2021]. According to them, companies usually start with simpler operational applications and only later implement more advanced strategic solutions. In practice, this means that different companies may be at different stages of AI adoption.

Büyüközkan i Göçer [2018] were among the first to describe the digital supply chain as a single, coherent system. Later studies, however, showed a more complex picture. Zekhnini i in. [2021] demonstrated that a company can be very advanced in one area of digitalization while lagging behind in another. Bag i in. [2021] indicate that the pace of AI implementation depends on the company's resources and the pressure from the environment. As a result, companies choose different digitalization paths.

The importance of technological infrastructure is emphasized by Sharabati i in. [2024]. Companies without adequate IT systems are unable to fully utilize the potential of AI. Queiroz et al. [2021], on the other hand, show that the pandemic exposed many such shortcomings and forced companies to make rapid investments in digital technologies.

Two important conclusions emerge from the existing research. First, the level of AI adoption in European manufacturing companies should be rather moderate, as many enterprises are still at an early stage of implementation [McKinsey 2023; OECD 2023]. Second, AI adoption is probably not homogeneous. Individual applications may develop at different rates.

On this basis, the following hypotheses were formulated:

H1: The adoption of AI in the supply chains of European manufacturing companies is moderate and even across application areas.

H3: The adoption of AI in supply chains is a homogeneous phenomenon—all application areas form a single construct. (This hypothesis was formulated for verification; based on previous research, its rejection is expected.)

The COVID-19 pandemic caused unprecedented disruptions in global supply chains. Borders were closed, production was limited, and transport costs rose sharply. Many companies experienced problems with the availability of raw materials and components for the first time.

Craighead i in. [2020] note that the pandemic was more than just a temporary crisis. It became a test of supply chain resilience. Companies that coped with this challenge often introduced lasting changes in the way they operated.

Ambrogio i in. [2022] show that the pandemic accelerated the digital transformation of enterprises. Many companies had to quickly implement digital tools to maintain supply continuity and monitor the situation of their suppliers. Processes that had previously been postponed were completed in a very short time.

Baldwin i Freeman [2022] observe that similar effects are caused by other external shocks, such as geopolitical tensions or transport disruptions. Under such conditions, companies reorganize their supply chains. At the same time, they increase the use of digital technologies, which improve process visibility and facilitate a quick response to problems.

Ivanov [2021] describes this phenomenon using the concept of supply chain viability. A resilient supply chain not only survives a crisis but is also able to adapt to it. Digitalization is one of the most important tools for this adaptation. The findings of Queiroz i in. [2022] confirm this relationship. Companies that invested more heavily in digital technologies during the pandemic returned to normal operations more quickly.

The literature thus suggests that the pandemic has left a lasting mark on the level of digitalization of enterprises. Companies more strongly affected by disruptions were more motivated to invest in digital solutions and should now exhibit a higher level of AI adoption.

Based on this, the following hypothesis was formulated:

H2: The COVID-19 pandemic has had a positive impact on the level of AI adoption—companies more strongly affected by pandemic disruptions show a higher level of supply chain digitalization.

Most studies assume that large companies implement new technologies faster than small enterprises. Acemoglu i Restrepo [2018, 2019] point out that automation and AI require significant financial outlays. Large companies usually have greater capabilities to finance such investments.

Brynjolfsson i McAfee [2014] highlight the importance of data. AI algorithms work more effectively when they have access to large data sets. Large enterprises gather more data than small companies, so they can more easily leverage the potential of artificial intelligence.

Sharabati i in. [2024] emphasize the importance of IT infrastructure. AI implementation is easier where modern ERP systems and data integration solutions are in place. Such systems are more common in large organizations.

Similar conclusions are presented by Sony i Naik [2020]. According to them, the main barrier for small companies is limited financial, technological, and personnel resources. Müller i in. [2018] show that SMEs face more difficulties implementing Industry 4.0 technologies than large enterprises. The OECD [2021] also points out that small companies lag behind in the use of advanced digital technologies.

The existing literature is therefore quite consistent. Larger enterprises have more resources, better infrastructure, and greater access to data. All these factors should support faster AI adoption. On this basis, the following hypothesis was formulated:

H4: Larger companies show a higher level of AI adoption in supply chains than small companies. Interestingly, the results of this study do not confirm this hypothesis with regard to operational AI. This unexpected result is discussed further in section 5.

2. Data and Methodology

The study is based on primary data collected via an online survey (CAWI) among 400 manufacturing companies from five Western European countries: France (n = 81), Germany (n = 78), the United Kingdom (n = 85), Italy (n = 80), and Spain (n = 76). The research was funded by the NCN Miniatura 8 grant (no. 625115). The data is publicly available at DOI: 10.71724/nnnz-tg10.

The questionnaire covered three thematic blocks corresponding to three types of exogenous shocks: disruptions caused by the COVID-19 pandemic (Q1–Q10), adoption of digital and AI technologies (Q11–Q20), and geopolitical disruptions related to the war in Ukraine (Q21–Q30). For each block, a synthetic index was calculated as the unweighted arithmetic mean of ten Likert-scale questions (scale 1–5). The indices were labeled COVID_score, TECH_score, and GEO_score, respectively.

The empirical analysis proceeds in four steps, each building on the previous one. Step 1 is descriptive statistics. These describe the level and variation of AI adoption in the technology block and allow for a preliminary comparison of countries.

Step 2 is correlation analysis between blocks. It examines whether companies that responded more strongly to the COVID-19 pandemic also show higher AI adoption. Spearman's rank correlation coefficient was used, as it is suitable for ordinal data and does not require a normal distribution assumption.

Step 3 is principal component analysis (PCA) with Varimax rotation. The aim is to check whether AI adoption is a homogeneous phenomenon or whether there are distinct dimensions within it. PCA reduces the ten variables to a few components that retain as much information as possible. Varimax rotation improves interpretability—each item loads strongly on one component and weakly on the others. Before analysis, the data was standardized (z-score). The number of components was determined based on interpretive criteria (three components explain a total of 59.5% of the variance), using the Kaiser criterion (eigenvalue ≥ 1) as a reference point. The Kaiser-Meyer-Olkin measure (KMO = 0.896, meritorious) and Bartlett's test of sphericity (χ^2 = 1049.15, df = 45, $p < 0.001$) confirmed the data are suitable for factor analysis. The reliability of the scale was confirmed with the Kaiser-Meyer-Olkin measure (KMO = 0.896, meritorious) and Bartlett's test of sphericity (χ^2 = 1049.15, df = 45, $p < 0.001$) confirmed the data are suitable for factor analysis. Cronbach's alpha (α = 0.837).

Step 4 is cluster analysis using the k-means method. It is based on the PCA results and allows identification of two types of companies—digital leaders and laggards. The optimal number of clusters was determined using the silhouette coefficient. Clusters were compared by country composition and company size.

3. Results

3.1. Overall Level of AI Adoption — What Companies Do with the Technology

The starting point for the analysis is descriptive statistics for the ten questions of the technology block (Table 1). The means of all items range from 2.82 to 3.15, i.e., close to the middle of the five-point scale. No area of AI adoption stands out as distinctly high or low.

The highest ratings were given to transport route optimization (Q19, M = 3.15) and efficiency of raw material procurement (Q17, M = 3.13). These are areas where the benefit of AI is direct and quickly measurable—shorter delivery times, lower unit costs. The lowest rating was given to inventory management (Q18, M = 2.82). Inventory management requires deeper integration of systems and historical data—implementation is more difficult and slower here.

Standard deviations (1.07–1.19) indicate moderate variation within the sample. This means that companies differ in their assessment of AI's impact, but there is no extreme polarization.

Table 1. Descriptive statistics – questions Q11–Q20 (N = 400)

Question	Area	M	SD	Med.	Min	Max
Q11	AI – chain shortening	3,09	1,19	3	1	5
Q12	Nearshoring – technology	2,94	1,12	3	1	5
Q13	Regional suppliers	3,03	1,10	3	1	5
Q14	Supplier optimization	3,06	1,08	3	1	5
Q15	AI – demand planning	3,00	1,16	3	1	5
Q16	Automation – labor shortages	2,99	1,08	3	1	5
Q17	AI – procurement	3,13	1,12	3	1	5
Q18	Digital – inventory management	2,82	1,07	3	1	5
Q19	AI – transport optimization	3,15	1,17	3	1	5
Q20	Real-time tracking	2,91	1,11	3	1	5

Note: Scale 1–5 (1 = no impact, 5 = very strong impact). Cronbach's α = 0.837.

3.2. Correlations Between Blocks — Did COVID Accelerate Digitization

Before examining the internal structure of AI adoption, it is worth addressing a broader question: did the COVID-19 pandemic leave a lasting mark on companies' digitization levels? Correlation analysis between blocks gives an affirmative answer.

The correlation between COVID_score and TECH_score is $r = 0.575$ ($p < 0.001$). This is a strong and highly statistically significant correlation. Companies that responded more strongly operationally to pandemic disruptions—shortening supply chains, diversifying suppliers, investing in digital tools during the crisis—now show higher levels of AI and automation adoption in their supply chains.

This result has important economic implications. The pandemic was not just a temporary shock—it was an accelerator of digital transformation. Companies that had

to quickly adapt their supply chains in 2020–2021 built digital competencies and infrastructure that they continue to use today.

Table 2. Correlations between synthetic block indices (Spearman's r, N = 400)

Block pair	Spearman's r	p	Interpretation
COVID_score × TECH_score	0,575	< 0,001	strong
COVID_score × GEO_score	—	—	no data
TECH_score × GEO_score	—	—	no data

Note: GEO_score – no comparable data due to differences in block structure. COVID_score and TECH_score calculated as unweighted means of 10 Likert items.

The COVID × TECH correlation is significant in all five countries but its strength varies (Table 3). It is strongest in the United Kingdom (r = 0.724) and Spain (r = 0.643), weakest in Germany (r = 0.302). The weaker correlation in Germany may be related to the specificity of its industrial model—large companies in the automotive and machinery sectors already had digital infrastructure before the pandemic and did not have to build it rapidly during the crisis.

Table 3. Correlation COVID_score × TECH_score by country (Spearman's r)

Country	Spearman's r	p
France	0.578	< 0.001
Germany	0.302	0.007
United Kingdom	0.724	< 0.001
Italy	0.528	< 0.001
Spain	0.643	< 0.001

Note: All correlations significant at p < 0.01 except Germany (p < 0.01).

3.3. PCA — Three Dimensions of AI Adoption

The correlation between blocks shows that companies with a stronger response to COVID are now more digitally advanced. The question remains: what does this mean in practice? Is AI adoption a single phenomenon or does it consist of different, independent dimensions?

PCA with Varimax rotation distinguishes three components, which together explain 59.5% of the variance in the ten technology block questions (Table 4). Each component corresponds to a different dimension of AI adoption.

The first component (RC1, 27.4% of variance) centers on questions about day-to-day internal operations: real-time tracking (Q20, loading 0.742), demand planning (Q15, 0.729), automation in response to labor shortages (Q16, 0.696), and inventory management (Q18, 0.631). This component can be called Operational AI. It describes the extent to which a company has integrated AI into ongoing production and logistics processes.

The second component (RC2, 17.5% of variance) includes questions about relationships with supply chain partners: use of regional suppliers thanks to digital tools (Q13, 0.808), transport route optimization (Q19, 0.624), and procurement

efficiency (Q17, 0.594). This is supplier integration—the digitization of the company–supplier interface.

The third component (RC3, 14.6% of variance) loads strongly on the attractiveness of nearshoring (Q12, 0.825) and supplier selection optimization (Q14, 0.720). This is strategic nearshoring—location and supply chain restructuring decisions motivated by technology.

Table 4. Factor loadings after Varimax rotation (PCA, 3 components, N = 400)

Item	RC1 – Operational AI	RC2 – Supplier Integration	RC3 – Strategic Nearshoring
Q11 – AI, chain shortening	0.523	0.449	0.080
Q12 – Nearshoring	0.076	0.272	0.825
Q13 – Regional suppliers	−0.033	0.808	0.266
Q14 – Supplier optimization	0.373	0.067	0.720
Q15 – AI, demand planning	0.729	0.184	0.170
Q16 – Automation, labor shortages	0.696	0.124	0.181
Q17 – AI, procurement	0.446	0.594	0.141
Q18 – Digital, inventory management	0.631	0.107	0.227
Q19 – AI, transport optimization	0.401	0.624	0.106
Q20 – Real-time tracking	0.742	0.103	0.198
% variance explained	27.4%	17.5%	14.6%

Note: Loadings ≥ 0.60 bolded for clarity. Total variance explained = 59.5%. Kaiser criterion met by PC1 and PC2 (eigenvalue > 1.0); PC3 (eigenvalue = 0.81) included for interpretability (nearshoring as a separate construct).

This result has important interpretive significance. AI adoption is not a single decision or indicator. A company can be a leader in operational AI and simultaneously a laggard in strategic nearshoring. This means that simplified digitization rankings may conceal important differences between companies.

3.4. Cluster Analysis — Who Are the Digital Leaders

Knowing that AI adoption has three dimensions, we can ask: do companies differ only in their degree of digital advancement, or do they form distinct clusters with different profiles?

K-means cluster analysis distinguishes two clusters. The silhouette coefficient is 0.238 for k = 2 and is higher than for k = 3, 4, and 5. The first cluster is Digital Laggards, comprising 296 companies (74% of the sample). The mean TECH_score is 2.69. The second cluster is Digital Leaders, comprising 104 companies (26% of the sample). The mean TECH_score is 3.92.

Table 5 shows that leaders outperform laggards in all ten questions. The largest difference concerns AI in demand planning (Q15, difference 1.54) and transport optimization (Q19, difference 1.50)—these are also the items most strongly loading

on RC1. This means that it is operational AI, not nearshoring or supplier integration, that most distinguishes leaders from laggards. All differences are statistically significant (Mann-Whitney test, $p < 0.001$).

Table 5. Cluster profiles of Digital Laggards and Digital Leaders — item means Q11–Q20

Item	Digital Laggards (n=296, 74%)	Digital Leaders (n=104, 26%)	Difference
Q11	2.73	4.13	1.40***
Q12	2.70	3.61	0.91***
Q13	2.81	3.67	0.87***
Q14	2.80	3.81	1.01***
Q15 – largest difference	2.60	4.14	1.54***
Q16	2.68	3.89	1.21***
Q17	2.75	4.18	1.43***
Q18	2.53	3.64	1.11***
Q19	2.76	4.26	1.50***
Q20	2.57	3.88	1.31***
TECH_score	2.69	3.92	1.23***

*Note: *** $p < 0.001$ (Mann-Whitney test, one-sided). $k = 2$, silhouette = 0.238.*

3.5. RC Component Profiles by Company Size and Country

PCA identified three dimensions of AI adoption. Cluster analysis showed who the leaders are. Now we can ask a more detailed question: in which dimension do small and large companies and companies from different countries differ?

Table 6 presents the mean RC component scores for four company size categories. The results are clear. Small companies (fewer than 50 employees) have by far the highest RC1 score (1.098)—almost twice as high as any other category. The difference is statistically significant ($H = 28.47$, $p < 0.001$). RC2 and RC3 do not differ significantly between size categories ($p > 0.33$).

This means that small companies stand out exclusively in the dimension of operational AI. They are leaders in everyday use of AI for their own processes: planning, tracking, inventory management. They do not outperform large companies in supplier integration or nearshoring decisions. One may hypothesize that small companies, with less bureaucracy and faster decision-making, find it easier to implement AI tools in daily operations, while their smaller negotiating power and resources limit supply chain reorganization at the strategic level.

Table 6. Mean RC1, RC2, RC3 component scores by company size

Company size	**RC1 AI oper.**	**RC2 Integration**	**RC3 Nearshoring**	**TECH_score**
< 50 employees	1,098	0,025	−0,066	3,40
50–250 employees	−0,086	−0,039	0,089	2,98
251–1000 employees	−0,520	−0,058	0,047	2,83
> 1000 employees	−0,264	0,146	−0,151	2,92
Kruskal-Wallis test	H=28,47***	H=3,42 ns	H=3,13 ns	—

*Note: RC — standardized PCA component scores (M = 0, SD ≈ 1). *** p < 0.001; ns — not statistically significant (Kruskal-Wallis test).*

Table 7 shows RC scores by country. The pattern is clear and consistent with the results of the correlations and cluster analysis. Only RC1 (Operational AI) differentiates countries significantly (H = 23.20, p < 0.001). RC2 and RC3 do not differ significantly between countries.

The United Kingdom has by far the lowest RC1 score (−0.699)—almost five times lower than Italy (+0.460) and four times lower than Spain (+0.352). Importantly, the UK does not differ on RC2 or RC3—British companies use digital tools in supplier relationships at a level comparable to other countries but implement AI in their own operations much less frequently. This result may be related to the effects of Brexit—regulatory uncertainty and reduced access to the EU market may have slowed operational transformation investments.

Table 7. Mean RC1, RC2, RC3 component scores by country

Country	**RC1 Operational AI**	**RC2 Integration**	**RC3 Nearshoring**	**N**
France	0.070	0.110	0.097	81
Germany	−0.126	−0.109	0.043	78
United Kingdom	−0.699	0.136	−0.017	85
Italy	0.460	−0.005	−0.098	80
Spain	0.352	−0.151	−0.025	76
Kruskal-Wallis test	H=23.20***	H=3.03 ns	H=2.10 ns	—

*Note: *** p < 0.001; ns — not statistically significant (Kruskal-Wallis test). Reference category in interpretation: United Kingdom.*

4. Discussion

The study provides four main empirical observations. First, AI adoption in European manufacturing companies is moderate. The averages for all ten questions are close to the middle of the five-point scale. Companies use AI and digital tools, but it cannot be described as widespread implementation. This result is consistent with studies for Western Europe—[McKinsey 2023] and [OECD 2023] indicate that full AI integration into production processes concerns only a minority of companies.

Second, the COVID-19 pandemic acted as an accelerator for digitalization. The correlation between the response to COVID and today's level of AI adoption is r =

0.575. Companies that shortened supply chains and invested in digital tools during the crisis now have a higher technological level. The pandemic forced rapid investment decisions, which left a lasting mark on digital competencies.

Third, AI adoption has three distinct dimensions. It is not a single phenomenon. PCA distinguishes operational AI, integration with suppliers, and strategic nearshoring. A company may be advanced in one dimension and lagging in another. This is an important observation for researchers and practitioners—aggregated digitalization indicators may mask significant differences.

Fourth, small companies are leaders in operational AI. As many as 44.3% of small firms (under 50 employees) are classified as Digital Leaders, compared to 23.5% of large firms. The difference concerns only RC1—everyday applications of AI in operations. In terms of supplier integration and nearshoring decisions, small companies do not outperform large ones.

The result concerning small companies is surprising. The prevailing view in the literature is that large companies, with greater financial resources and IT staff, are quicker to implement new technologies (Acemoglu & Restrepo, 2018). The results of this study indicate the opposite pattern in the segment of operational AI. Two possible explanations exist. First, small companies have a simpler organizational structure. Implementing a new tool requires fewer procedures, fewer decision-making levels, and less coordination between departments. Implementation speed is a competitive advantage. Second, large companies have a greater technological legacy. Old ERP systems and databases hinder the integration of new AI solutions. Small companies, not having old systems, implement new tools on a clean slate. This result requires further investigation. The survey data do not allow us to determine which of these hypotheses is correct. Panel data or in-depth interviews with managers would be needed.

The United Kingdom achieves the lowest RC1 score among all five countries (−0.699). This result is clearly different from the others. The difference between the UK and Italy in RC1 exceeds 1.1 standardized points. At the same time, the UK does not lag behind in RC2 or RC3. British companies are comparable to other countries in terms of digital integration with suppliers and nearshoring decisions. The weakness concerns only internal operations. Interpretation is difficult based solely on the survey data. Brexit may have increased regulatory uncertainty and prompted companies to be cautious in operational investments. A structural explanation is also possible—the service sector has a larger share in the UK than in Germany, Italy, or Spain, which may translate into a lower level of automation in manufacturing companies. Resolving this issue requires a separate study.

The study has three main limitations. The first concerns the nature of the data. Survey data measure managers' subjective assessments, not objective indicators of AI implementation. Responses may be affected by social desirability bias—respondents may overestimate the modernity of their company. The second concerns geographical coverage. The sample includes five Western European countries. The results cannot be generalized to Central and Eastern Europe, where the level of AI adoption and industry structure are different. The third concerns PCA. The three-component solution explains 59.5% of the variance, which is within acceptable norms for survey

data. Some unique variance is natural and expected. The factor structure may be different in samples from other countries or industries.

Conclusions

The aim of the article was to analyze the adoption of digital technologies and AI in the supply chains of European manufacturing companies based on primary data from five countries (N = 400). Descriptive statistics, correlation analysis between thematic blocks, principal component analysis (PCA), and k-means cluster analysis were used.

The results lead to three practical conclusions. First, the digitalization of supply chains is not homogeneous. Companies and decision-makers should distinguish between operational AI, supplier integration, and strategic nearshoring. Digitalization support policies should be tailored to the specific dimension that requires intervention. A single general support program for digitalization does not address the real needs of companies.

Second, small companies require a different approach than large ones. They are leaders in operational AI but laggards in the strategic reorganization of the supply chain. Support programs for SMEs should focus not on implementing operational tools—where small companies manage on their own—but on access to supplier networks and support for nearshoring decisions.

Third, the COVID-19 pandemic has left a lasting and measurable mark on the level of digitalization in companies. Economic policies that supported digital investments during the pandemic had a long-term effect. This is an argument for maintaining digitalization support programs in future crises, before their negative economic effects occur.

Further research directions include three areas. The first is to extend the sample to companies from Central and Eastern Europe. This would allow for verification of whether the observed patterns are specific to Western Europe. The second is longitudinal research—data from subsequent years would make it possible to assess whether digital leaders identified in 2022 maintain their advantage. The third is an in-depth qualitative analysis of small companies that, contrary to expectations, dominate in operational AI.

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PROCESS GOVERNANCE AND ORGANIZATIONAL RESILIENCE IN PUBLIC HEALTHCARE SYSTEMS: A BPM-BASED APPROACH IN TIMES OF DIGITAL TRANSFORMATION

Abhishek Dorle[13]

Streszczenie

Niniejszy artykuł koncepcyjny analizuje relacje między Zarządzaniem Procesami Biznesowymi (BPM), zarządzaniem procesami i odpornością organizacyjną w publicznych podmiotach leczniczych. Opierając się na modelu dojrzałości BPM i teorii odporności, proponuje ramy koncepcyjne łączące standaryzację procesów, odpowiedzialność opartą na rolach, mechanizmy kontrolne i monitorowanie efektywności z odpornością organizacyjną w warunkach transformacji cyfrowej [Dumas et al. 2018]. W artykule wskazano, że zarządzanie procesami wzmacnia odporność poprzez ograniczanie fragmentacji, zwiększanie odpowiedzialności oraz redukcję warunków sprzyjających oszustwom, marnotrawstwu i nadużyciom (FWA). Podkreślono, że transformacja cyfrowa zwiększa potrzebę skutecznego zarządzania. Artykuł kończy się przedstawieniem agendy badawczej oraz praktycznych wniosków dla menedżerów opieki zdrowotnej, właścicieli procesów i decydentów [Lengnick-Hall, Beck and Lengnick-Hall 2011].
Słowa kluczowe: zarządzanie procesami biznesowymi, zarządzanie procesami (process governance), odporność organizacyjna, transformacja cyfrowa, oszustwa, marnotrawstwo i nadużycia, publiczne systemy opieki zdrowotnej

Summary

This conceptual paper examines the relationship between Business Process Management (BPM), process governance, and organizational resilience in public healthcare provider organizations. Drawing on BPM maturity and resilience theory, it proposes a conceptual framework linking standardized workflows, role-based accountability, control mechanisms, and performance monitoring to organizational resilience in digitally transforming healthcare environments [Dumas et al. 2018]. The paper argues that process governance strengthens resilience by reducing fragmentation, embedding accountability, and mitigating conditions enabling Fraud, Waste, and Abuse (FWA). It highlights digital transformation as increasing the need for effective governance. The paper concludes with a research agenda and practical implications for healthcare managers, process owners, and policymakers [Lengnick-Hall, Beck and Lengnick-Hall 2011].
Keywords: business process management, process governance, organizational resilience, digital transformation, fraud waste and abuse, public healthcare systems

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Introduction

Contemporary public healthcare organizations operate at the confluence of escalating regulatory demands, rapid digital transformation, and persistent efficiency pressures. The management of provider-side healthcare billing and reimbursement workflows — a process critical to the financial integrity and operational continuity of healthcare systems—has emerged as a high-risk domain where governance failures carry far-reaching consequences. In European public healthcare systems alone, Fraud, Waste, and Abuse (FWA) associated with fragmented billing, documentation, and reimbursement workflows is estimated to result in losses exceeding €1.2 billion annually [OLAF 2022]. These losses are not primarily attributable to technological deficiency, but rather to structural weaknesses in process governance: unclear process ownership, inconsistent control execution, and the absence of systematized performance feedback loops.

Simultaneously, digital transformation—encompassing the deployment of AI-assisted validation tools, automated workflow systems, blockchain-based audit trails, and advanced process analytics—is fundamentally redefining how healthcare processes are designed, monitored, and governed. However, the literature suggests that technological adoption without commensurate governance reform often exacerbates rather than resolves organizational fragmentation [de Bruin and Rosemann 2007]. Organizations that invest in digital tools while neglecting process governance maturity are likely to replicate existing inefficiencies in new technological form [Pollitt and Bouckaert 2017].

Organizational resilience—the capacity to anticipate, adapt to, and recover from disruptive change—has attracted growing scholarly attention in the context of healthcare management [Lengnick-Hall, Beck and Lengnick-Hall 2011]. Yet the specific mechanisms through which process governance contributes to resilience in public healthcare organizations, particularly during periods of digital transition, remain undertheorized. This paper addresses this gap by proposing a conceptual framework that positions BPM-based process governance as a structural antecedent of organizational resilience in provider-side healthcare billing and documentation workflows.

The paper is structured as follows. Section 2 reviews the theoretical underpinnings of BPM, process governance, and organizational resilience. Section 3 identifies the key challenges facing public healthcare billing and documentation workflows in the context of digital transformation. Section 4 presents the conceptual framework. Section 5 discusses implications for research and practice, followed by concluding remarks in Section 6.

1. Theoretical Background

1.1 Business Process Management and Process Governance

Business Process Management (BPM) is a holistic management discipline focused on the systematic identification, design, execution, documentation, measurement, monitoring, and continuous improvement of organizational processes [Dumas et al. 2018]. BPM theory has evolved considerably from early process re-engineering paradigms toward a capability-oriented perspective, wherein organizational BPM maturity reflects not only technical sophistication but also structural, cultural, and governance dimensions [de Bruin and Rosemann 2007].

Process governance refers to the structural and procedural arrangements by which process-related decisions are made, controlled, and monitored within an organization [de Bruin and Rosemann 2007]. It encompasses process ownership structures, accountability frameworks, standard operating procedures (SOPs), control mechanisms, and performance management systems. Effective process governance ensures that BPM initiatives are not merely technical exercises but are embedded in organizational accountability structures that drive consistent, compliant, and improvable behavior.

In public sector organizations, process governance assumes additional significance due to the mandatory compliance requirements, public accountability obligations, and the constraints of operating within politically and legally bounded environments. Healthcare provider-side billing and reimbursement workflows — Including clinical documentation, coding validation, internal data verification, and billing preparation—exemplify the high-stakes nature of public sector process governance.

1.2 Organizational Resilience: Theoretical Perspectives

Organizational resilience is a multidimensional construct that has been conceptualized in diverse ways across management, systems theory, and organizational psychology literatures. Resilience can be understood as comprising three interrelated elements: cognitive (the capacity to interpret threats accurately), behavioral (the capacity to respond adaptively), and contextual (the structural conditions that enable flexible response) [Lengnick-Hall, Beck and Lengnick-Hall 2011]. In healthcare management, resilience theory has been applied to understand how hospitals and healthcare systems maintain continuity of service delivery under adverse conditions, including pandemics, resource constraints, and technological disruption.

A process-centric view of resilience emphasizes the role of standardized, well-governed operational processes as structural buffers against disruption. When processes are clearly defined, roles are unambiguously assigned, and control

mechanisms are consistently enforced, organizations are better positioned to detect anomalies early, localize disruptions, and execute recovery routines efficiently. Conversely, organizations with fragmented, poorly governed processes are more vulnerable to cascading failures when confronted with disruptive change—precisely the condition that characterizes many public healthcare systems undergoing digital transformation [Duchek 2020].

1.3 Digital Transformation in Public Healthcare: Opportunities and Governance Challenges

Digital transformation in healthcare has advanced rapidly, encompassing the deployment of electronic health records (EHRs), AI-driven clinical decision support, automated billing and reimbursement management platforms, and emerging blockchain applications for audit trail integrity [Vial 2021]. These technologies offer substantial potential for efficiency gains and compliance improvements. Automated validation and billing support systems, for example, can process high volumes of claims with reduced cycle times and more consistent rule application than manual workflows.

However, technology adoption in isolation does not constitute governance reform [Gil-Garcia, Dawes and Pardo 2020]. The literature on digital transformation in public organizations consistently identifies governance gaps as a primary implementation barrier [Mergel, Edelmann and Haug 2019]. When digital tools are layered onto pre-existing fragmented process architectures, organizations risk amplifying existing inefficiencies rather than resolving them. Furthermore, the introduction of algorithmic decision-making into regulated healthcare processes raises new governance questions concerning explainability, accountability, and auditability—domains where BPM-based frameworks are particularly relevant.

1.4 Governance Challenges in Provider-Side Billing and Documentation Workflows

Healthcare provider organizations operate a complex reimbursement workflow in which clinical documentation, coding accuracy, internal validation, and billing preparation must be coordinated before submission to the payer. In public healthcare settings, this process is not a payer-side adjudication function; rather, it is a provider-side operational workflow that determines whether claims are submitted accurately, completely, and in compliance with regulatory and contractual requirements.

The provider-side process typically begins with patient encounter documentation and the capture of clinical services provided. These records must then be translated into accurate codes and billing-relevant data through charge capture and coding

activities. Before submission, the organization must verify the completeness and consistency of clinical, administrative, and billing information, correct documentation errors, and ensure that the claim package meets payer and regulatory requirements. Only after these internal checks can the claim be submitted to the payer or national reimbursement authority.

From a governance perspective, this workflow is highly sensitive to process fragmentation, unclear responsibility, inconsistent control execution, and weak feedback loops. If documentation standards are unclear or if process ownership is diffuse, errors may propagate through the workflow, leading to rejected claims, delayed reimbursement, rework, and compliance exposure. Poorly governed billing processes may also create conditions that increase the risk of Fraud, Waste, and Abuse (FWA), particularly where audit trails are incomplete, controls are inconsistent, or the same staff member performs multiple incompatible tasks without adequate segregation of duties [Najar et al. 2025].

The transition to digital systems introduces additional governance requirements. Electronic health records, billing platforms, automated validation tools, and process analytics can improve efficiency, but only when supported by standardized workflows, clear accountability, and embedded control mechanisms. Without such governance, digital tools may simply reproduce existing inefficiencies in automated form. For this reason, provider-side digital transformation must be accompanied by process governance reform that strengthens documentation quality, coding accuracy, submission reliability, and the organization's ability to detect and correct errors early.

In this context, BPM-based process governance becomes a critical structural enabler of operational resilience. A well-governed provider-side billing workflow supports continuity, compliance, and adaptability under changing regulatory, technological, and organizational conditions. It enables healthcare organizations to respond more effectively to disruptions, reduce rework and claim rejections, and maintain financial and operational stability during digital transformation.

2. A Conceptual Framework: Process Governance as a Driver of Organizational Resilience

2.1 Framework Overview

The proposed framework conceptualizes the relationship between BPM-based process governance, digital transformation readiness, and organizational resilience in public healthcare provider-side billing and documentation workflows. It is grounded in three theoretical pillars: BPM maturity theory [de Bruin and Rosemann 2007], organizational resilience theory [Lengnick-Hall, Beck and Lengnick-Hall

2011] and institutional theory as applied to public sector governance [Pollitt and Bouckaert 2017]. The framework identifies five core governance mechanisms that collectively constitute process governance capability, and posits that each mechanism contributes distinctly to resilience dimensions while mediating the effects of digital transformation [DiMaggio and Powell 1983].

2.2 Core BPM Governance Mechanisms

The framework identifies five governance mechanisms central to resilient provider-side billing and documentation workflows [Ribeiro, Barata and da Cunha 2024]:

1. The systematic mapping of provider-side billing and documentation workflows using BPMN notation, the formalization of standard operating procedures (SOPs), and the maintenance of up-to-date process documentation. Standardization reduces interpretive ambiguity and ensures that process knowledge is organizationally codified, enabling consistent execution, improved documentation quality, and more reliable billing submission processes [Dumas et al. 2018] .

2. Role-Based Accountability and Process Ownership: The clear assignment of process ownership responsibilities [de Bruin and Rosemann 2007], including accountability for process outcomes, authority to implement process changes, and obligation to monitor performance. Process ownership structures ensure that governance responsibility is not diffused across the organization but concentrated in designated roles with corresponding authority.

3. Embedded Control Points and Audit Trail Mechanisms: The systematic integration of verification checkpoints, segregation of duties, multi-level verification checkpoints, and comprehensive audit trail documentation into the process architecture. Embedded controls serve as proactive deterrents to FWA-enabling conditions by making deviation detectable and attributable [de Bruin and Rosemann 2007] [Ribeiro, Barata and da Cunha 2024].

4. KPI-Based Performance Monitoring and Feedback: The deployment of structured performance measurement systems covering process quality (error rates, rework volumes), efficiency (cycle time, throughput), and compliance dimensions. KPI-based feedback enables organizations to detect performance degradation early, distinguish systemic from individual causes, and deploy targeted corrective actions.

5. Continuous Improvement Governance: The institutionalization of Root Cause Analysis (RCA), Corrective and Preventive Action (CAPA) management, and process re-design cycles as ongoing governance activities. Continuous improvement governance ensures that process learning is captured, acted upon, and embedded into

revised process standards—constituting the adaptive dimension of organizational resilience.

2.3 Governance Mechanisms and Resilience Dimensions

The framework proposes that the five governance mechanisms contribute to organizational resilience across three dimensions: anticipative resilience [Lengnick-Hall, Beck and Lengnick-Hall 2011] (the capacity to foresee and prepare for disruption), absorptive resilience [Lengnick-Hall, Beck and Lengnick-Hall 2011] (the capacity to withstand and localize disruption), and adaptive resilience [Lengnick-Hall, Beck and Lengnick-Hall 2011] (the capacity to learn and reconfigure following disruption). Process standardization and embedded control mechanisms primarily enhance absorptive resilience by reducing variability and localizing failure effects. KPI-based monitoring and process ownership structures enhance anticipative resilience by enabling early anomaly detection and ensuring clear responsibility for preventive action. Continuous improvement governance primarily enhances adaptive resilience by embedding organizational learning into process re-design cycles [Sincorá et al. 2023].

2.4 Digital Transformation as a Governance Moderator

The framework conceptualizes digital transformation not as a direct driver of resilience, but as a moderating variable whose effects on resilience are mediated by the level of process governance maturity [Vial 2021]. Organizations with high governance maturity are positioned to leverage digital tools—AI-assisted validation, process mining, blockchain audit trails—as amplifiers of existing governance capabilities. Organizations with low governance maturity risk using these same tools to institutionalize existing deficiencies at scale. This governance-technology interaction implies that digital transformation strategy in public healthcare must be explicitly coupled with governance reform, rather than treated as a standalone technological initiative [Mergel, Edelmann and Haug 2019].

The framework also acknowledges the institutional context of public healthcare governance. Public sector organizations operate within regulatory frameworks—national health insurance laws, EU regulatory directives, GDPR compliance requirements—that both constrain and enable governance reform. Institutional pressures may create isomorphic tendencies toward formal governance adoption (mimetic isomorphism) or generate coercive compliance requirements [DiMaggio and Powell 1983] that may or may not align with operational governance effectiveness. The proposed framework therefore treats institutional context as an important boundary condition for governance-resilience relationships.

2.5 Governance–Resilience Relationship Framework

The proposed framework advances a conceptual governance–resilience relationship framework for understanding how BPM-based process governance may support organizational resilience in public healthcare systems undergoing digital transformation. Rather than treating resilience primarily as a behavioural, cultural, or leadership-driven capability, the framework conceptualizes resilience as partially embedded within governance architecture and operational process design [Duchek 2020].

Within this perspective, governance mechanisms such as process standardization, role-based accountability, embedded controls, KPI-driven monitoring, and continuous improvement systems collectively strengthen an organization's capacity to anticipate, absorb, and adapt to operational disruption. These governance mechanisms reduce process fragmentation, improve procedural consistency, and enhance organizational visibility across critical healthcare workflows.

The framework therefore suggests that stronger alignment between governance structures and operational execution may contribute to higher organizational resilience during periods of institutional and technological change [Sincorá et al. 2023].

The framework further proposes that digital transformation functions as a governance capability amplifier rather than an independent resilience driver. Organizations possessing mature governance capabilities are better positioned to leverage digital technologies—including workflow automation, process analytics, interoperable health information systems, and AI-assisted decision-support tools—to strengthen operational resilience and process stability. Conversely, organizations with fragmented governance structures risk reproducing existing inefficiencies and control deficiencies within newly digitized environments.

The framework contributes to existing BPM and organizational resilience literature by introducing a process-centric perspective in which governance architecture functions as an important structural enabler of resilience within public healthcare systems [Ribeiro, Barata and da Cunha 2024]. It further provides a conceptual basis for future empirical investigation into how governance maturity may influence organizational adaptability, compliance stability, process quality, and the mitigation of governance-related operational risks in digitally transforming healthcare environments.

3. Discussion: Implications for Research and Practice

3.1 Theoretical Contributions

This paper makes several contributions to the theoretical discourse on BPM, healthcare management, and organizational resilience. First, it advances the conceptualization of process governance as a structural antecedent of resilience, extending resilience theory [Duchek 2020] beyond its predominant focus on leadership, culture, and individual adaptive capacity to include process architecture as a systemic resilience mechanism [Sincorá et al. 2023]. Second, it provides a domain-specific application of BPM governance theory to public healthcare provider-side billing and documentation workflows — a context that, despite its operational significance, has received limited empirical attention in the BPM literature. Third, the paper theorizes the governance-technology interaction in digital transformation processes, offering a conceptual basis for understanding why technology adoption without governance reform is unlikely to generate resilient outcomes [Dumas et al. 2018].

3.2 Research Agenda

The conceptual framework generates several empirically testable propositions. The following research directions are identified as priorities:

- Empirical validation of the relationship between BPM governance maturity and organizational resilience outcomes in public healthcare organizations, using mixed-methods research designs combining qualitative interviews with quantitative survey instruments.
- Process mining studies examining the relationship between process standardization quality and provider-side billing and documentation workflows cycle time, rework volumes, and compliance rates in digitally transformed healthcare provider environments [Munoz-Gama 2022].
- Comparative cross-national studies examining how different EU public healthcare governance regimes moderate the governance-resilience relationship, contributing to an EU system comparison relevant to policy harmonization objectives.
- Longitudinal assessment of governance intervention effects in public healthcare organizations undergoing digital transformation, using pre-post KPI designs to evaluate changes in process quality, efficiency, and FWA-enabling conditions.

3.3.Ongoing Empirical Research

The conceptual framework presented in this paper forms the theoretical foundation of the author's ongoing doctoral research at the Warsaw University of Technology. The empirical phase is currently being developed using a mixed-methods research design. It will include semi-structured interviews with healthcare managers and process owners, followed by a quantitative survey to examine the relationships between BPM-based process governance mechanisms and organizational resilience in public healthcare provider organizations. The proposed governance model will subsequently be analytically validated through a case study supported by process performance indicators (KPIs). The findings from this empirical research are expected to provide evidence for the proposed governance–resilience relationships and refine the conceptual framework.

3.4. Practical Implications for Healthcare Managers and Policymakers

For healthcare managers, the framework provides a structured governance improvement agenda organized around five actionable mechanisms. The priority sequencing implied by the framework suggests that process standardization and process ownership structures should be established before digital tools are deployed, ensuring that automation amplifies rather than embeds existing deficiencies. Performance monitoring systems should be designed to generate governance-relevant KPIs—not merely operational throughput metrics—enabling the detection of governance degradation as a leading indicator of resilience risk.

For policymakers, the framework suggests that digital transformation funding and regulatory frameworks for public healthcare systems should include explicit governance maturity requirements as preconditions for technology investment [Pollitt and Bouckaert 2017]. EU health system comparison objectives would benefit from the development of standardized process governance maturity benchmarks, enabling cross-national learning and policy harmonization. Regulatory frameworks targeting FWA reduction should emphasize upstream process governance reform in addition to downstream detection and enforcement mechanisms [Najar et al. 2025].

4. Integrated Conceptual Framework

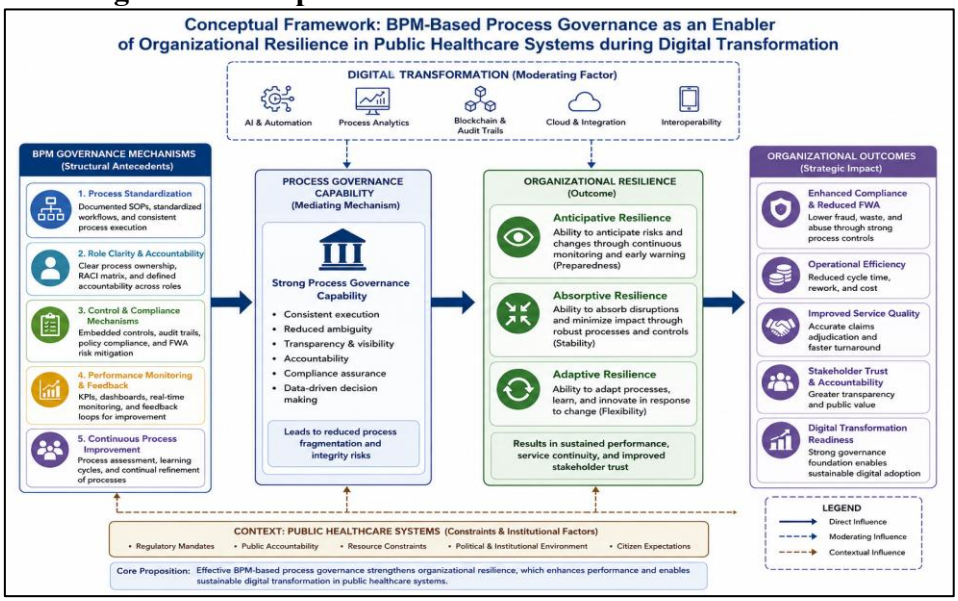

Figure 1. Integrated Conceptual Framework
Source: Author's own elaboration

Conclusion

This paper has argued that BPM-based process governance constitutes a foundational driver of organizational resilience in public healthcare systems confronting digital transformation. The proposed conceptual framework identifies five core governance mechanisms—process standardization, process ownership accountability, embedded control points, KPI-based performance monitoring, and continuous improvement governance—and theorizes their distinct contributions to anticipative, absorptive, and adaptive resilience dimensions. The framework positions digital transformation as a governance moderator whose effects on resilience depend critically on the level of process governance maturity attained before and during technological transition.

The practical implications of this framework are substantial. Public healthcare systems across Europe and beyond are investing substantially in digital transformation initiatives while continuing to experience governance-driven inefficiencies, FWA-related financial losses, and compliance failures. The argument advanced here—that governance reform must precede and accompany, rather than follow, digital transformation—offers a reorientation of transformation strategy with significant implications for both healthcare management practice and public policy.

Future research should empirically test the framework within Polish public healthcare provider organizations undergoing digital transformation. The ongoing

doctoral research underpinning this paper will contribute empirical evidence through mixed-methods research combining qualitative interviews with healthcare managers and quantitative governance surveys, followed by case study validation and KPI-based evaluation of governance model implementation.

This empirical validation is currently being undertaken as part of the author's doctoral research at the Warsaw University of Technology using a sequential mixed-methods design comprising qualitative interviews, quantitative surveys, and case study validation.

In sum, as public healthcare organizations navigate the complexities of digital change, the consolidation of process governance capabilities is not merely a management improvement objective—it is a strategic resilience imperative. Organizations and people operating in times of change require structural anchors that enable adaptive, accountable, and efficient response: BPM-based process governance provides precisely these anchors.

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PART III.

PEOPLE, HUMAN CAPITAL AND RESILIENCE IN TIMES OF CHANGE

Knapková (2026), Household Work Organization in Slovak Households: Role Allocation, Routines and Tensions [in:] Piekut, M., & Luque Vílchez, M. (Eds.), Organizations, People and Sustainable Transformation in Times of Change, Kolegium Nauk Ekonomicznych i Społecznych, Politechnika Warszawska, Płock.

HOUSEHOLD WORK ORGANIZATION IN SLOVAK HOUSEHOLDS: ROLE ALLOCATION, ROUTINES AND TENSIONS

Miroslava Knapková[14]

Streszczenie
Rozdział analizuje organizację nieodpłatnej pracy domowej w słowackich gospodarstwach domowych. Na podstawie danych ankietowych z projektu VEGA 1/0536/24, obejmujących 976 respondentów, zbadano jasność ról, podział zadań, rutyny oraz nieporozumienia. Wyniki wskazują, że praca domowa jest organizowana głównie nieformalnie, elastycznie i sytuacyjnie. Najczęstszą zasadą podziału zadań jest dostępność czasu, natomiast stały przydział obowiązków występuje rzadko. Większość respondentów wskazała spontaniczną organizację pracy, a ponad połowa deklarowała przynajmniej sporadyczne nieporozumienia. Różnice ze względu na płeć dotyczyły jedynie podziału zadań, natomiast typ gospodarstwa domowego wiązał się ze wszystkimi analizowanymi wymiarami..
Słowa kluczowe:praca domowa, praca nieodpłatna, zarządzanie gospodarstwem domowym, podział ról, Słowacja.

Summary
The chapter examines the organization of unpaid household work in Slovak households. Based on questionnaire data from the VEGA 1/0536/24 project and 976 respondents, it analyses role clarity, task allocation, routines and disagreements. The findings show that household work is mostly organized informally, flexibly and situationally. Available time is the most common principle of task allocation, while fixed assignment is rare. Most respondents reported spontaneous organization, and more than half indicated at least occasional disagreements. Gender differences appeared only in task allocation, while household composition was related to all analyzed dimensions.
Key words: household work, unpaid work, household management, role allocation, Slovakia.

JEL: D13, J16, J22, Z13

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Introduction

Unpaid household work is a necessary condition for the everyday functioning of households, yet it is often treated as a secondary or invisible form of labor. In contemporary societies, households face changing work patterns, economic pressures, care needs and shifting family arrangements. In this chapter, "people in times of change" refers to these everyday changes in paid work, family structures and care responsibilities, which affect not only formal organizations and labor markets, but also the ways in which domestic responsibilities are allocated, coordinated and negotiated within households [Haskova and Klenner, 2010; Boďa et al., 2024].

This chapter focuses on the organizational dimension of unpaid household work in Slovak households. Instead of analyzing the total volume of domestic work, it examines how household work is organized: whether roles and responsibilities are clearly defined, how tasks are allocated among household members, whether domestic work follows routines or remains spontaneous, and whether tensions arise in relation to its organization.

The aim of the chapter is to identify basic patterns of household work organization in Slovakia and to examine whether these patterns differ by gender and household composition. The analysis is guided by the following research questions: RQ1: How clear are roles and responsibilities in household work organization? RQ2: What are the dominant principles of task allocation? RQ3: How are household routines organized? RQ4: Do role clarity, task allocation, routines and tensions differ by gender and household composition? By conceptualizing the household as an informal organizational space, the chapter contributes to the broader discussion on organizations and people in times of change.

1. Literature Review

Unpaid household work is not only a set of domestic tasks, but also a field of everyday organization. Within households, work is allocated, coordinated, routinized and negotiated. The domestic sphere therefore represents an informal organizational space that differs from formal organizations, but nevertheless involves role definition, temporal coordination and informal decision-making [Boďa et al., 2024; Coltrane, 2000; Brumley and St. George, 2025]. This perspective is useful because it shifts attention from the amount of unpaid work to the way in which domestic responsibilities are organized.

The division of domestic labor is usually explained through three main perspectives. The time availability approach assumes that domestic tasks are allocated according to the available time of household members [Gershuny and Sullivan, 2014]. The relative resources approach links domestic labor to bargaining power and economic resources [Cooke, 2006]. The gender ideology perspective stresses the role

of norms and expectations that shape domestic responsibilities beyond purely rational calculations [Trübner, 2022]. These explanations often operate simultaneously and their relevance depends on household structure, life-course stage and institutional context, including the specific post-socialist development of Central and Eastern European countries [Haskova and Klenner, 2010].

Empirical research shows that household work is often not organized through explicit rules or fixed task allocation. Many households rely on flexible, situational and implicit forms of coordination [Wiesmann et al., 2008; Craig et al., 2016]. Domestic work is repetitive and responsive to changing needs, which makes rigid organization difficult [Alberts et al., 2011]. Informal organization should not be understood as the absence of order. Rather, households often operate through habitual patterns, implicit expectations and gradual negotiation between members [Mannino and Deutsch, 2007].

The temporal organization of household work is therefore important. Fixed schedules are relatively rare, while flexible or orientational arrangements allow households to respond to changes in work, school, care needs or unexpected events [Moro, 2025]. Such spontaneity may be functional, but it can also make domestic labor less visible, especially when tasks performed 'as needed' are unequally recognized or assumed by some household members [Rinaldo and Whalen, 2023]. Tensions may then arise not only from the amount of work, but also from perceived fairness, recognition and responsibility [Cleveland et al., 2014; Trübner, 2022].

Gender remains a persistent dimension of household labor. Women generally perform more unpaid work and are more often responsible for routine and time-inflexible tasks, while men's contributions are more often linked to occasional tasks [Román and Ophir, 2024]. At the same time, gender differences may be less visible in some organizational dimensions, such as perceived role clarity, routines or conflict frequency [Kümmerling et al., 2025]. Household composition is also crucial: single-person households, couples, households with children and multigenerational households face different coordination demands [Gershuny and Sullivan, 2014; Craig et al., 2016]. In Slovakia, previous research documents persistent gender inequalities in household work and the continuing importance of family and intergenerational arrangements [Knapková and Považanová, 2021; Boďa et al., 2024; Považanová et al., 2019].

Overall, the literature suggests that unpaid household work should not be analyzed only through the amount of time spent on domestic tasks. Its organizational dimension is equally important. Household work involves role allocation, routines, flexibility, implicit expectations and tensions. The present paper builds on this perspective by examining four selected dimensions of household work organization in Slovak households: role clarity, task allocation, routine arrangements and disagreements

related to domestic work. By focusing on the household as an informal organizational space, the study contributes to the broader discussion on organizations and people in times of change.

2. Methodology

The empirical analysis is based on data collected within the research project VEGA 1/0536/24 – Management of Slovak Households and Decision-Making on Unpaid Work in the Post-COVID Economy, financially supported by the Ministry of Education, Research, Development and Youth of the Slovak Republic. The project focuses on the functioning of Slovak households, with particular attention to household management, the organization of unpaid work, and decision-making processes related to everyday domestic responsibilities.

For the purposes of this paper, only a selected part of the questionnaire was used. The aim was not to analyze unpaid household work in its full scope, but to focus specifically on its organizational dimension. The paper therefore examines how household work is allocated, whether household members have clearly defined responsibilities, whether domestic work follows any form of routine or schedule, and whether tensions occur in relation to its organization.

The study is based on a cross-sectional questionnaire survey. The unit of analysis is the individual respondent, who reports on the organization of work in his or her household. The analytical sample consists of 976 respondents. The sample is treated as an exploratory analytical sample rather than as a probability sample of all Slovak households. Data were collected in March and April 2025. Respondents were recruited using a snowball sampling method and through trained interviewers who approached households without targeting any specific household type. Participation in the survey was voluntary, and all respondents provided prior consent to share information and complete the questionnaire. The questionnaires were anonymous; respondents were not identified by name, and interviewers recorded questionnaires only by codes.

All variables used in this paper contain valid responses from the full sample. Women represented 61.6% of the sample, men 38.0%, and 0.4% of respondents selected another gender category. In terms of household composition, the largest group consisted of young adults living with their parents, representing 41.0% of the sample (Table 1). Other household types included individuals living alone, couples without children, households with children, single-parent households, multigenerational households and other arrangements. This structure is important for interpretation, as the organization of household work may differ depending on the life-cycle stage and composition of the household.

Table 1. Structure of research sample

Sample characteristic	N	Percent
Total sample	976	100
Women	601	61.6
Men	371	38.0
Other gender category	4	0.4
Largest household type - Young adults living with parents	406	41.0

Source: own elaboration

The paper uses four core questionnaire items. These items were selected because they directly capture the dimensions derived from the theoretical framework: role definition, task allocation, routine arrangements and tensions connected with household work. The selection was therefore purposive and theory-driven. The aim was not to analyze unpaid household work in its full scope, but to focus specifically on its organizational dimension (Table 2).

Table 2. Variables used in the analysis

Analytical dimension	Questionnaire item	Type of variable
Role clarity	Household members have clearly divided tasks and know what they are responsible for.	Five-point agreement scale
Allocation of domestic work	How do you most often divide household work among members of your household?	Categorical variable
Routine arrangements	Do you have any form of schedule or regularly established organization of household work?	Categorical variable
Everyday tensions	How often do disagreements or disputes occur in connection with the organization of household work?	Ordinal categorical variable

Source: own elaboration

The first item measures the perceived clarity of roles and responsibilities in the household. Respondents evaluated the statement on a five-point agreement scale ranging from strong disagreement to strong agreement. The second item captures the

dominant way in which domestic work is allocated among household members, for example according to available time, age and abilities, fixed task assignment, or situational need. The third item identifies whether the household uses a fixed schedule, an orientational schedule, or whether domestic work is organized spontaneously. The fourth item measures how often disagreements or disputes arise in relation to the organization of household work.

In addition to these four substantive variables, two classification variables were used: gender and household composition. Gender was included because previous research on unpaid work repeatedly points to gendered patterns in domestic responsibilities. Household composition was included because the organization of household work is likely to differ between single-person households, households with parents and adult children, couples, families with children, single-parent households and multigenerational households.

For gender comparisons, only male and female respondents were included, as the "other gender category" consisted of only four respondents and was therefore excluded from chi-square testing.

The analysis is descriptive and exploratory. Frequency distributions and percentage shares are used to describe the main patterns. Associations between categorical variables are tested using Pearson's chi-square test of independence, which is appropriate for examining whether the distribution of responses differs across gender and household-type categories. The significance level was set at $p < 0.05$. Cramer's V is reported as an effect-size measure. Due to low counts in some household-type categories, especially single-parent households, results by household composition should be interpreted as exploratory. No missing responses were recorded for the variables used in the article.

3. Results

The analysis focuses on four dimensions of household work organization: 1. clarity of roles and responsibilities, 2. allocation of domestic tasks, 3. routine arrangements, and 4. tensions related to the organization of household work.

3.1. Role clarity in household work organization

The first analyzed dimension concerned whether household members have clearly divided tasks and know what they are responsible for. The results indicate that role clarity is present only in part of the analyzed households. Overall, 24.0% of respondents fully agreed and 18.1% partially agreed that household members have clearly divided tasks and responsibilities. Thus, 42.1% of respondents expressed some level of agreement with this statement.

At the same time, 30.5% of respondents selected the neutral category. This indicates that for a considerable part of the sample, household responsibilities are neither clearly formalized nor entirely absent. A further 27.4% of respondents disagreed, either fully or partially (Table 3). These results suggest that the organization of household work is often characterized by a relatively high degree of ambiguity in the allocation of responsibilities.

Table 3. Clarity of roles and responsibilities in household work (in the whole sample and divided by gender)

	Whole sample		**Males**		**Females**	
Response	Frequency	%	Frequency	%	Frequency	%
Strongly disagree	116	11.9	41	11.1	75	12.5
Partially disagree	151	15.5	48	12.9	103	17.1
Neither disagree nor agree	298	30.5	114	30.7	183	30.5
Partially agree	177	18.1	70	18.9	106	17.6
Strongly agree	234	24.0	98	26.4	134	22.3
Total	976	100.0	371	100.0	601	100.0

Source: own elaboration

The gender comparison did not show statistically significant differences in perceived role clarity, $\chi^2(4, N = 972) = 4.83$, $p = 0.306$, Cramer's V = 0.070. Among men, 45.3% partially or fully agreed that household members have clearly divided tasks, compared with 39.9% of women (Table 3). The difference is not statistically significant and the effect size is very small.

Differences by household type were statistically significant, $\chi^2(24, N = 976) = 42.50$, $p = 0.011$, Cramer's V = 0.104. However, the effect size was small and some categories had lower expected counts; therefore, the results should be interpreted cautiously. The highest level of full agreement was found among couples without children, where 39.0% of respondents fully agreed that roles are clearly divided. By contrast, among respondents living with parents, only 18.7% fully agreed with the

statement. This suggests that role clarity may be more explicit in couple households without children than in households where adult children live with parents.

3.3 Allocation of domestic tasks among household members

The second dimension examined how domestic work is most often divided among household members. The most frequent organizing principle was allocation according to available time, reported by 31.5% of respondents (Table 4). The second most common answer was that everyone does what is currently needed, selected by 23.6% of respondents. Allocation according to age and abilities was reported by 19.0% of respondents.

Table 4. Main ways of allocating domestic work in households (in the whole sample and divided by gender)

	Whole sample		**Males**		**Females**	
Way of allocating household work	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**
I perform household work myself	117	12.0	34	9.2	83	13.8
According to age and abilities	185	19.0	84	22.6	100	16.6
According to available time	307	31.4	105	28.3	202	33.6
Tasks are fixed and assigned	63	6.4	28	7.5	33	5.5
Everyone does what is currently needed	230	23.6	90	24.3	139	23.1
Another established way	74	7.6	30	8.1	44	7.3
Total	976	100.0	371	100.0	601	100.0

Source: own elaboration

Only 6.5% of respondents stated that tasks are fixed and assigned to specific household members. This is an important finding because it indicates that formal or

stable task assignment is not the dominant model of household work organization. Instead, the data point to flexible, situational and adaptive modes of organization.

If the two categories "according to available time" and "everyone does what is currently needed" are interpreted as flexible arrangements, they together represent 55.1% of responses. This confirms that the internal organization of household work is usually based more on everyday adjustment than on fixed division of labor.

Gender differences in task allocation were statistically significant, $\chi^2(5, N = 972) = 12.37$, $p = 0.030$, Cramer's $V = 0.113$. The effect size was small, but the result indicates that men and women differ in how they describe the allocation of household work. Women more often reported allocation according to available time (33.6 %), while men more often reported allocation according to age and abilities (22.6 %).

Differences by household type were also statistically significant, $\chi^2(30, N = 976) = 224.68$, $p < 0.001$, Cramer's $V = 0.215$. The effect size was moderate compared with the other analyzed relationships. This result is substantively meaningful, because household composition directly shapes the possible ways in which unpaid work can be allocated.

Table 5. Allocation of domestic work by household type (in %)

Household type	Living alone	Living with parents	Couple without children	Couple with children	Single-parent household	Multigenerational household	Other arrangement
I do it myself	54.5	5.7	12.2	6.8	11.2	7.7	13.5
Age and abilities	5.7	22.2	6.5	25.2	25.9	21.2	16.2
Available time	11.4	33.0	48.0	32.0	29.6	23.1	24.3
Fixed assignment	5.7	4.4	7.2	8.7	3.7	11.5	8.2
Current need	15.9	27.3	22.0	19.9	14.8	28.8	24.3
Other way	6.8	7.4	4.1	7.4	14.8	7.7	13.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: own elaboration

In single-person households, 54.5% of respondents stated that they perform household work themselves (Table 5). This is expected given the absence of other household members. Among respondents living with parents, the most common

responses were allocation according to available time (33.0%) and everyone doing what is currently needed (27.3%). Among couples without children, allocation according to available time was especially prominent, reaching 48.0%. In households with children, the most frequent principles were available time (32.0%) and age and abilities (25.2%). This suggests that in households with children, the allocation of domestic work is more strongly linked to the capacities and positions of individual household members.

Due to low counts in some household-type categories, especially single-parent households, the results of chi-square tests by household composition should be interpreted as exploratory.

3.4 Routine arrangements and spontaneous organization

The third analyzed dimension concerned whether households use any form of schedule or regularly established organization of domestic work. The results show that spontaneous organization clearly dominates. A total of 62.0% of respondents stated that household work is organized spontaneously and performed according to the situation and current needs. An orientational schedule was reported by 30.4% of respondents, while only 7.6% reported having a fixed schedule (Table 6).

Table 6. Schedule and routine arrangements in household work organization (in the whole sample and divided by gender)

	Whole sample		**Males**		**Females**	
Form of organization	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**
Fixed schedule	74	7.6	33	8.9	40	6.7
Orientational schedule	297	30.4	122	32.9	174	29.0
Spontaneous organization	605	62.0	216	58.2	387	64.3
Total	976	100.0	371	100.0	601	100.0

Source: own elaboration

These findings reinforce the previous results on task allocation. Household work is usually not organized through fixed systems. Instead, it tends to rely on situational coordination, orientational routines and everyday responsiveness to current needs.

Gender differences in routine arrangements were not statistically significant, $\chi^2(2, N = 972) = 4.10$, $p = 0.128$, Cramer's $V = 0.065$. Women reported spontaneous

organization somewhat more often than men, but the difference was not statistically significant. Specifically, 64.3% of women and 58.2% of men reported that household work is organized spontaneously.

Differences by household type were statistically significant, $\chi^2(12, N = 976) = 51.68$, $p < 0.001$, Cramer's V = 0.163. Spontaneous organization dominated across most household types. It was most frequent in other household arrangements (67.6%), households with children (66.5%) and households where respondents lived with parents (65.8%). Single-person households showed the highest proportion of fixed schedules (22.7%). Despite these differences, the general pattern remains consistent: household work is usually organized spontaneously rather than through fixed schedules.

3.5 Tensions related to household work organization

The fourth dimension examined the frequency of disagreements or disputes connected with the organization of household work. The largest group of respondents, 41.1%, reported that such disagreements occur occasionally (Table 7). Another 10.5% stated that they occur often. Together, 51.6% of respondents therefore reported at least occasional tensions related to the organization of domestic work.

At the same time, 27.3% of respondents stated that disagreements almost never occur and 14.1% reported that they do not occur at all. A further 7.1% indicated that household work is not organized in their household.

The data show that household work organization is not a conflict-free area of everyday life. Although frequent disputes are reported by a minority of respondents, occasional disagreements are relatively common. This supports the interpretation that domestic work organization involves negotiation, expectations and implicit responsibilities, not only the technical allocation of tasks.

Gender differences in the frequency of disagreements were not statistically significant, $\chi^2(4, N = 972) = 2.64$, $p = 0.620$, Cramer's V = 0.052. Men and women reported similar levels of tensions. Occasional or frequent disagreements were reported by 49.6% of men and 52.8% of women.

Table 7. Frequency of disagreements related to household work organization (in the whole sample and divided by gender)

	Whole sample		**Males**		**Females**	
Frequency of disagreements	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**
Household work is not organized	69	7.1	22	5.9	45	7.5
Not at all	138	14.1	58	15.6	80	13.2
Almost never	266	27.3	107	28.8	159	26.5
Occasionally	401	41.1	146	39.4	254	42.3
Often	102	10.4	38	10.3	63	10.5
Total	976	100.0	371	100.0	601	100.0

Source: own elaboration

Differences by household type were statistically significant, $\chi^2(24, N = 976) = 59.01$, $p < 0.001$, Cramer's V = 0.123. The highest combined share of occasional or frequent disagreements was found in multigenerational households, where 65.3% of respondents reported at least occasional tensions (Table 8). High shares were also observed among respondents living with parents (56.1%) and households with children (59.2%). By contrast, respondents living alone reported the lowest level of occasional or frequent disagreements, 36.3%, which is consistent with the fact that there are fewer intra-household negotiations over the distribution of tasks.

These findings suggest that tensions are more frequent in households where more members are involved and where responsibilities are likely to require greater coordination. Multigenerational households and households with children appear to be particularly exposed to everyday negotiation over domestic work.

Table 8. Disagreements related to household work organization by household type (in %)

Household type	Living alone	Living with parents	Couple without children	Couple with children	Single-parent household	Multigenerational household	Other arrangement
Work not organized	8.0	6.2	6.5	7.8	11.2	5.8	9.5
Not at all	27.3	12.3	22.0	9.7	14.8	3.8	14.9
Almost never	28.4	25.4	35.0	23.3	29.6	25.0	35.1
Occasionally	22.7	43.3	29.3	50.5	37.0	53.8	36.5
Often	13.6	12.8	7.2	8.7	7.4	11.6	4.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: own elaboration

4. Discussion

The findings show that household work organization in the analyzed Slovak sample is predominantly informal, flexible and situational. This corresponds with previous research suggesting that domestic work is often organized through implicit understandings, routines and micro-negotiations rather than through formal rules or fixed task assignment [Wiesmann et al., 2008; Mannino and Deutsch, 2007].

Role clarity was present only in part of the sample. Although 42.1% of respondents partially or fully agreed that household members have clearly divided tasks and know what they are responsible for, many respondents selected the neutral category or disagreed. This indicates relatively ambiguous responsibility structures, consistent with the socially embedded character of domestic work [Coltrane, 2000].

The most frequent principle of task allocation was available time, followed by the rule that everyone does what is currently needed. Fixed assignment of tasks was rare. This supports the relevance of the time availability perspective, although the present paper does not test it as an explanatory model. Such flexibility may help households adapt to changing schedules and everyday demands, but it can also leave responsibilities open to interpretation and become a source of tension [Cleveland et al., 2014; Trübner, 2022].

The dominance of spontaneous organization confirms the informal character of household management. Nearly two thirds of respondents reported that domestic work

is organized spontaneously according to the situation and current needs, while only a small minority reported a fixed schedule. Spontaneous organization should therefore not be interpreted simply as disorganization; it may also represent adaptive capacity in changing socio-economic conditions [Moro, 2025].

Tensions related to household work organization were relatively common. More than half of respondents reported that disagreements occur at least occasionally. Frequent disputes were not dominant, but occasional tensions appear to be a regular part of household organization. This finding supports the interpretation of domestic work as a negotiated and relational process rather than a purely technical distribution of tasks.

Gender differences were statistically significant only in the way domestic work is allocated. Women more often reported allocation according to available time, while men more often reported allocation according to age and abilities. No statistically significant gender differences were found in role clarity, routine arrangements or frequency of disagreements. This does not mean that gender is irrelevant; rather, it suggests that gender may be more visible in the quantity and type of unpaid work than in all perceived organizational dimensions [Román and Ophir, 2024; Kümmerling et al., 2025].

Household composition was associated with all four analyzed dimensions. This indicates that the organization of unpaid work is strongly shaped by household structure. Single-person households necessarily organize domestic work differently from households with several members, while households with children, multigenerational households and households where respondents live with parents require more coordination and showed higher levels of tensions. This confirms the need to analyze domestic work through household type and life-course context, not only through gender [Gershuny and Sullivan, 2014; Craig et al., 2016].

The contribution of the paper lies in shifting attention from the amount of unpaid work to its organizational dimension. Domestic work is allocated, coordinated, routinized and negotiated. Households are not formal organizations, but they perform organizational functions and represent an important site of everyday socio-economic coordination.

Conclusion

The chapter examined the organization of unpaid household work in Slovak households through four dimensions: role clarity, task allocation, routine arrangements and tensions. The findings show that household work is mostly organized in an informal, flexible and situational way. Clear role division was reported only by part of the respondents, while fixed assignment of domestic tasks was rare. The most common organizing principles were available time and current household

needs. Similarly, most respondents reported spontaneous organization of household work rather than a fixed schedule.

The results also show that flexibility does not eliminate tensions. More than half of the respondents reported at least occasional disagreements related to the organization of household work. Gender differences were statistically significant only in task allocation, while household composition was associated with all analyzed dimensions. This suggests that the organization of unpaid work is shaped not only by gender, but also by the structure and complexity of the household. Households with children, multigenerational households and households where respondents live with parents appear to require more coordination and are more exposed to everyday tensions.

The main contribution of the chapter lies in shifting attention from the volume of unpaid work to its organizational dimension. Domestic work is not only performed; it is allocated, coordinated, routinized and negotiated. In this sense, households can be understood as informal organizational spaces and as relevant sites of everyday socio-economic coordination.

The study has several limitations. The analysis is descriptive and exploratory and does not establish causal relationships. The data are based on self-reported perceptions of one respondent, not on matched responses from all household members. The structure of the sample, especially the high share of respondents living with parents, also limits the generalization of the findings. Despite these limitations, the results provide useful empirical evidence on how unpaid household work is organized in Slovak households and point to the importance of further research on household management, role allocation and intra-household coordination.

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HEALTHCARE CONSUMPTION PATTERNS OF HOUSEHOLDS WITH DEPENDENT CHILDREN

Justyna Karwowska[15]

Streszczenie

W opracowaniu dokonano analizy poziomu i struktury wydatków na zdrowie ponoszonych przez gospodarstwa domowe, koncentrując się na gospodarstwach, w skład których wchodzą dzieci. W latach 2004-2024 zaobserwowano wyraźny trend wzrostowy w zakresie wydatków zdrowotnych w Polsce. Małżeństwa bezdzietne przeznaczają najwięcej środków na opiekę zdrowotną, podczas gdy rodziny wielodzietne charakteryzują się najniższym udziałem wydatków zdrowotnych w wydatkach ogółem. Wykorzystując dane za rok 2023 przeprowadzono analizę skupień w wyniku której wyselekcjonowano 3 grupy gospodarstw domowych z dziećmi, różniące się modelem konsumpcji zdrowotnej. Wydatki gospodarstw domowych z dziećmi na utrzymaniu w 2023 r. wykazały znaczną różnorodność w zależności od poziomu dochodów, miejsca zamieszkania, liczby dzieci oraz wykształcenia reprezentanta gospodarstwa domowego. Jednocześnie zauważa się, że zdecydowana większość tych gospodarstw ponosi stosunkowo niskie wydatki na zdrowie i charakteryzuje się skromnym modelem konsumpcji zdrowotnej, ograniczając się do zaspokojenia podstawowych potrzeb.
Słowa kluczowe: wydatki na zdrowie, gospodarstwa domowe, rodziny z dziećmi, wzorce konsumpcji

Summary

This study analyzes the level and structure of health expenditures incurred by households, focusing on households with children. The user represents an extended trend in expenditures between 2004 and 2024. Childless couples account for the largest share of health expenditures, while large families are characterized by expenditures that are allocated to public spending. Using data for 2023, a controlled clustering approach was used, resulting in the selection of three groups of households with children, each differing in their territorial pattern. Expenditures of households with children in 2023 were determined by the scope of their involvement, place of residence, number of children, and household ownership. Limiting factors that are applied when applying these principles are applied in everyday life and in nature, in the case of a typical consumption pattern limited to meeting basic needs.
Key words: health expenditure, households, families with children, consumption patterns

JEL: D12, D13, I11, I14

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Introduction

Health-related expenditures constitute a significant component of household budgets. They encompass, among other things, medical and pharmaceutical products, medical devices and equipment, as well as outpatient, hospital, and sanatorium services. Their level and structure reflect the economic situation of households and the extent of the demand for medical services and supplies. In turn, the factors determining private healthcare financing are the age and education level of the household representative, as well as income [Piekut, Gutkowska 2016: 43].

In recent years, a growing share of household health expenditure has been observed, resulting from increased public awareness regarding preventive healthcare [Gutkowska, Piekut 2016: 43], rising prices for medicines and medical services, and limited access to medical services. According to the Public Opinion Research Center (CBOS), the majority of Poles believe that medical treatment in Poland is not free (73% of respondents), and 64% seek treatment outside the universal health insurance system (either exclusively or partially). The growing financial burden on households contributes to the phenomenon of "catastrophic expenditure" - defined as a very high level of healthcare spending relative to income. This leads to a deterioration of the economic situation, thereby increasing the risk of poverty and deepening social inequalities [Aliński 2025], [Piekut 2023], [Golinowska 2018]. Healthcare addresses fundamental needs. When faced with the necessity of increased health-related spending, households often have to forgo meeting other basic needs, such as purchasing food or maintaining their housing [Łyszczarz 2018]. Furthermore, during times of financial hardship, households forgo meeting certain health needs, such as purchasing medications or visiting the dentist [Kacprzak, Trębska and Wielewska 2018].

Out-of-pocket healthcare spending is often linked to the level of public funding in the sector. Poland is among the countries with the lowest healthcare expenditure relative to GDP - ranking just behind Luxembourg and Ireland - with spending at 6.7% of GDP in 2022 [OECD 2024]. Funds allocated to prevention and public health in Poland are among the lowest in the EU and have been declining in recent years (approximately 2%, compared to nearly 8% in Germany) [Kwiatkowska et al. 2025].

Healthcare expenditures have a distinct impact on households with dependent children. The composition of these households, the developmental needs of their youngest members, and the higher frequency of medical service utilization result in a specific pattern of health-related consumption. At the same time, lower per-capita income, resulting from the need to spread earnings across a larger number of individuals, means these households operate under tighter financial constraints than childless households [Bitana, Lachore, and Utallo 2024]. Consequently, private health spending may be lower in relative terms, despite the family's greater health needs.

Research indicates that the presence of children and elderly individuals increases a household's health needs [Shahraki and Ghaderi 2021], [Sette and Coelho 2020]. On the other hand, M. Piekut [2014] notes that healthcare expenditures are lowest in lower-income households with a larger number of children.

Analyzing healthcare consumption makes it possible to determine the extent of the financial burden on households and to identify groups particularly vulnerable to rising healthcare costs.

The aim of this study is to determine the level of health-related expenditure and its share of total household spending, taking into account changes over time and family types and to distinguish groups of households characterized by distinct patterns of healthcare consumption.

In relation to the objective formulated in this way, the following research questions were posed:

- How did the level and share of household health expenditure change between 2004 and 2024?
- Does the biological type of the family affect the level of healthcare expenditure incurred?
- What other characteristics influence the financing of health goods and services by households with children?
- What are the household groups based on health-related consumption patterns?

This objective was achieved using data provided by Statistics Poland, an agency that collects, processes, and disseminates statistics and data regarding the economic, social, and demographic situation in Poland. This enables the formulation of generalized conclusions and supports state institutions in planning social and health policies.

The conducted research provides a multidimensional analysis of health-related expenditures incurred by households in Poland, particularly those with children, between 2004 and 2024. This study fills a research gap, as households with children are rarely analyzed as a distinct socio-economic group.

1. Material and research methodology

The research material used in this study consisted of data from Eurostat, data from Statistics Poland's household budget surveys covering the years 2004–2024, and individual-level data from the 2023 household budget surveys. Households with dependent children which comprising 9,221 cases were selected from unpublished 2023 Statistics Poland data. The objective was to identify groups of households characterized by similar patterns of health-related consumption. The variables

analyzed were expenditures on seven categories of health-related goods and services, namely:

- pharmaceutical products;
- prescription glasses and contact lenses, hearing aids, repair of therapeutic devices and equipment, other therapeutic devices and equipment;
- medical services – general practitioners and specialists;
- dental services;
- medical laboratory and X-ray services; thermal baths, corrective gymnastics, emergency medical services, and therapeutic equipment rental; and services related to medical support and alternative medicine;
- hospital and sanatorium services;
- pregnancy tests and mechanical contraceptives; other medical devices not elsewhere classified.

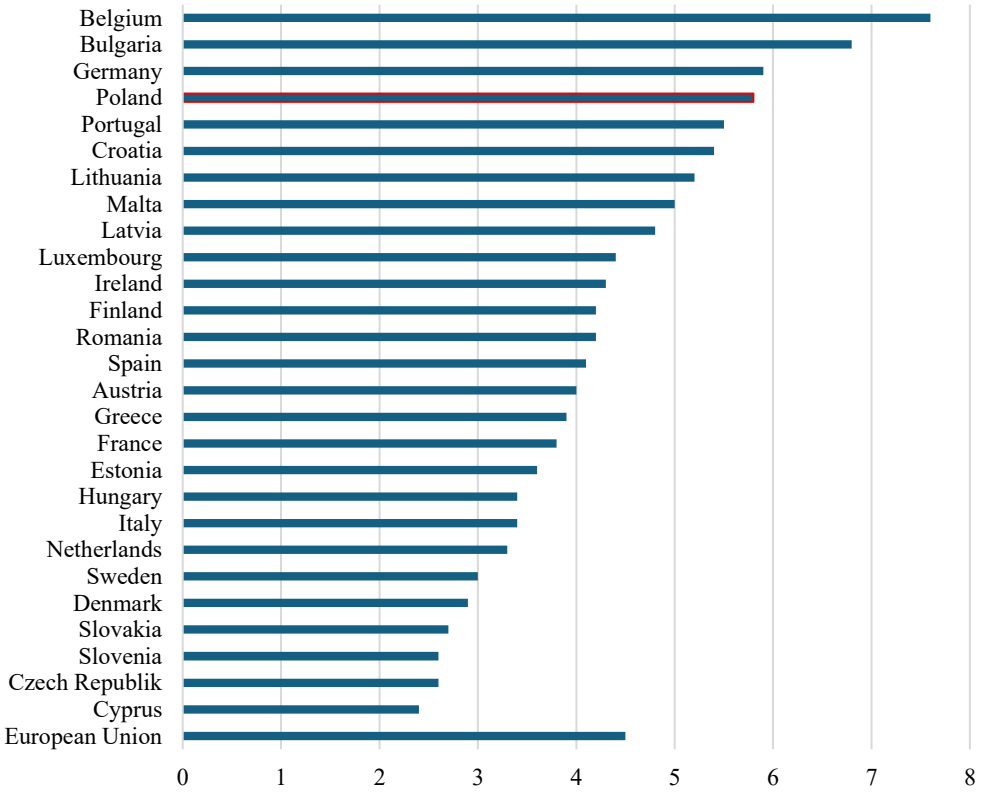
Farms were grouped using k-means cluster analysis based on Euclidean distance. The analysis initially divided the farms into five clusters; however, two of these contained a small number of cases and were consequently excluded from the study. Ultimately, the farms were categorized into three groups, each comprising more than 150 cases, resulting in a total of 9,024 households. Descriptive statistical measures—specifically the arithmetic mean and expenditure structures—were also employed in the study.

Statistical analysis was performed using Excel and Statistica 13.3 software.

2. Health expenditure in European households

International comparisons make it possible to assess how different European Union countries fund healthcare and the financial burden healthcare places on households. This study presents the share of health expenditure within total consumer spending across EU countries in 2024 (Chart 1). The highest health expenditures were recorded in Belgium (7.6%), Bulgaria (6.8%), and Germany (5.9%), while the lowest were in Cyprus (2.4%), the Czech Republic (2.6%), and Slovenia (2.6%). Poland ranked fourth in terms of the share of private health expenditure, which stood at 5.8% in 2024, indicating a significant burden on households. With the EU average at 4.5%, Polish households allocated 1.3 percentage points more of their consumer spending to health than their European counterparts.

Chart 1. Share of health expenditures in total consumer spending in European households in 2024 (in %)



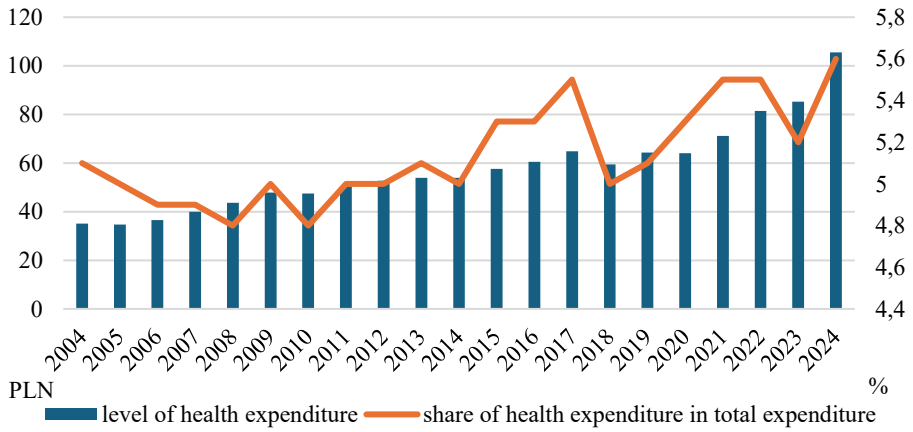
Source: Eurostat. Household final consumption expenditure by purpose (COICOP 2018) [nama_10_cp18__custom_20553498]

3. Health expenditure in Polish households, 2004–2024

Based on an analysis of household budget survey data, it was found that per capita health care spending in Polish households more than tripled between 2004 and 2024: from PLN 35 in 2004 to nearly PLN 106 in 2024 (Chart 2). Meanwhile, the share of this expenditure category in total expenditures fluctuated—in some years it increased, while in others it decreased (from 4.8% in 2008 to 5.6% in 2024). The largest decline in both the share and the level of household health-related expenditures was recorded in 2018 compared to the previous year (by 0.5 percentage points—5.4 PLN per person). On the other hand, in 2024, compared to the previous year, there was a marked increase in both the share and the level of health care expenditures (by 0.4 percentage points, or 20.3 PLN per person). The reasons for the increase in healthcare spending include, among others, rising prices of medications and medical services, as

well as an aging population [National Institute of Public Health NIH – National Research Institute 2025], [Piekut and Gutkowska 2016], [Golinowska 2003].

Chart 2. Level of health expenditure and its share of total expenditure in Polish households, 2004–2024



Source: prepared by the author based on: Statistics Poland (2005–2025), Household Budget Survey in 2004–2024, Warsaw.

The presence of children in a household has a significant impact on consumption patterns. Therefore, household health expenditures were analyzed according to the criterion of biological family type. The analysis covered the years 2023 and 2024, as a marked increase in these expenditures was observed during that period.

The results indicate that an increase in both the level and the share of health-related expenditure was recorded across all analyzed household groups (Table 1). In both years analyzed, the highest expenditure was observed among households consisting of married couples without children (161 PLN per person in 2024, representing 6.3%). Conversely, the lowest figures were observed among married couples raising three or more children. An exception occurred in 2024, when the lowest share was recorded among married couples with two dependent children (4.2%). It is worth noting that in all household groups with children, the level and share of health-related expenditure were lower than the national average.

The largest increase in the share of health-related expenditure was observed among married couples raising at least three children, with a rise of 0.7 percentage points compared to the previous year. Studies show that as the number of children increases, households face greater difficulties in financing health and educational goods and services [Bitana, Lachore, and Utallo, 2024], [Piekut, 2014]. They also sometimes resort to external financing to meet educational and health needs [Das, 2023].

Table 1. Level (PLN) and share (%) of health expenditure in total expenditure of Polish households by family type in 2023 and 2024

Specification	Level of expenditure (in PLN)		Share of expenditure in total expenditure (in %)	
	2023	2024	2023	2024
Childless marriage	133.35	161.42	5.9	6.3
Married couple with one dependent child	77.35	101.63	4.3	4.8
Married couple with two dependent children	62.12	71.99	4.1	4.2
Married couple with at least three dependent children	47.03	65.46	3.9	4.6
Mother/father with at least one dependent child	76.41	92.33	4.3	4.6
Overall	85.29	105.56	5.2	5.6

Source: prepared by the author based on: Statistics Poland (2024–2025), Household Budget Survey in 2023 and Household Budget Survey in 2024, Warsaw.

4. Groups of households with dependent children by health expenditure

The next step involved examining healthcare consumption patterns among households with dependent children in 2023. A cluster analysis identified three household groups based on seven categories of health-related expenditure (Table 2).

Cluster I, comprising over two-thirds of all households, was characterized by the lowest levels of spending across all health expenditure categories—ranging from PLN 0.64 for hospital and sanatorium services to PLN 11.76 for pharmaceutical products (Table 3). Total health expenditure in this group amounted to PLN 27.84 per person. These households had the lowest per capita income, standing at PLN 2,133.25 in 2023. Compared to the other groups, households in Cluster I were more likely to be located in rural areas (over 48%) and in smaller towns with fewer than 99,000 inhabitants (14%). A relatively small percentage of these households lived in large cities; approximately 15% of the surveyed households were located in cities with populations exceeding 200,000. Households with two dependent children were the most common in Cluster I (37%). Representatives of households in this cluster most frequently held a secondary education (36%) and were less likely to have a higher education compared to those in other clusters (32% versus 35–46% in the other clusters) (Table 4).

Cluster II comprised 2,391 households. They were characterized by expenditure levels for almost all the health-related categories discussed that were higher than those in Cluster I but lower than those in Cluster III. An exception was expenditure on sanatorium and hospital services, which was highest in this group (PLN 2.88 per person, compared to PLN 0.64–1.38 in the other clusters). Spending on pharmaceutical products amounted to PLN 63.27 per person, followed by expenditure on general practitioner and specialist services (PLN 9.13 per person) and dental services (PLN 6.16). Total health expenditure amounted to PLN 90.70 per person. The

average monthly disposable income per person in households within this group stood at PLN 2,326.13. Representatives of these households most frequently held a higher education degree (approx. 35%); furthermore, there was a larger share of individuals with basic vocational education compared to the other clusters (approx. 29%, versus 18% in Cluster III and 27% in Cluster I). As with Cluster I, these households were located primarily in rural areas (approx. 47%), followed by cities with populations of 20,000–99,000 (approx. 20%)—the highest percentage for this category among the clusters.

Cluster III, the smallest, comprised 513 households (approx. 6% of the surveyed group). It was distinguished by the highest level of health-related spending—over PLN 231 per person across all health expenditure categories. Pharmaceutical products accounted for over 72% (PLN 167 per person) of these expenses, followed by medical services—provided by general practitioners and specialists—at approximately 10% (PLN 23 per person). Medical laboratory and X-ray services ranked third, accounting for about 8% (PLN 19 per person). Disposable income was highest in this cluster (PLN 2,705). Households in this cluster were more likely than those in other clusters to be located in cities with populations of 100,000 or more (38%). Members of these households were the oldest (average age of 46) and had the highest proportion of individuals with higher education (46% relative to the other groups). These were primarily households with one dependent child (59%), while the average household size in this cluster was the lowest (4.2).

Table 2. K-means clustering results in 2023

Cluster number	Number of cases	Percent
1	6120	67.8
2	2391	26.5
3	513	5.7

Source: individual data from the 2024 Statistics Poland Household Budget Survey.

Table 3. Level of health expenditure and its share of total health expenditure in households with dependent children

Specification	Level of expenditure			Share of expenditure		
Cluster number	**I**	**II**	**III**	**I**	**II**	**III**
Pharmaceutical products	11.76	63.27	166.71	42.2	69.8	72.1
Pregnancy tests and mechanical contraceptives; other medical devices not elsewhere classified	0.78	1.73	2.83	2.8	1.9	1.2
Prescription glasses and contact lenses, hearing aids, repair of therapeutic devices and equipment; other therapeutic devices and equipment	3.11	3.87	7.01	11.2	4.3	3.0
Medical services – general practitioners and specialists	4.77	9.13	22.99	17.1	10.1	9.9
Dental services	4.75	6.16	11.70	17.1	6.8	5.1
Medical laboratory and X-ray services; thermal baths, corrective gymnastics, emergency medical services, and rental of therapeutic equipment; and medical support and alternative medicine services.	2.04	3.65	18.65	7.3	4.0	8.1
Hospital and sanatorium services	0.64	2.88	1.38	2.3	3.2	0.6
Total health expenditure	27.84	90.70	231.27	100%	100%	100%

Source: individual data from the 2024 Statistics Poland Household Budget Survey.

Table 4. Characteristics of household types with dependent children

Types of households	1 cluster	2 cluster	3 cluster
Disposable income per capita	2,133.25	2,326.13	2,705.05
Average number of persons per household	4.7	4.7	4.2
Average age of the household representative	43.5	44.5	46.1
Representative's level of education:			
Higher	32.0	34.9	45.7
Medium	35.7	32.4	30.6
Basic vocational	26.7	28.5	18.0
At most a lower-secondary education	5.7	4.1	5.7
Households located in:			
Towns: 500 or more inhabitants	9.1	8.6	23.2
Towns: 200,000–499,000 inhabitants	6.0	6.0	7.1
Towns: 100,000–199,000 inhabitants	7.4	5.6	8.1
Towns: 20,000–99,000 inhabitants	15.5	20.3	11.0
Towns: fewer than 20,000 inhabitants	13.7	12.5	13.3
Village	48.3	47.0	37.3

Number of dependent children up to the age of 24:			
1 child	33.5	39.6	59.0
2 children	36.9	35.7	30.7
3 children	25.0	19.7	10.0
4 or more children	4.7	5.0	0.3

Source: individual data from the 2024 Statistics Poland Household Budget Survey.

Conclusion

The results of the analysis demonstrate that Poland is among the countries with a high share of household spending on healthcare. Between 2004 and 2024, per capita health expenditure more than tripled. Furthermore, the share of such spending within total expenditure fluctuated significantly. In the final year of the analysis—2024—this share reached its highest level for the entire period under review, with a marked increase also recorded compared to the previous year.

The reasons for higher health expenditure include:

1. Higher prices for medical services, medicines, or diagnostics.
2. Greater need to use paid services due to queues, a shortage of specialists, or a limited scope of covered services.
3. Households may increasingly view health as a more important area of expenditure than before—particularly in the post-pandemic context and given heightened health awareness.
4. An increase in the number of benefits utilized, e.g., due to higher morbidity or greater availability of private medical services.

The highest healthcare expenditures were recorded in households of childless married couples, while the lowest were found in large families and households with two dependent children. Similar patterns were observed regarding the share of healthcare spending within total expenditure. It is also worth noting that across all household groups with dependent children, both the absolute level and the share of healthcare spending were below the national average. Households with children incur significantly higher living costs (food, transport, education, recreation, clothing), leaving a smaller portion of income available for healthcare; furthermore, the incomes of these households tend to be lower. Moreover, households with children make greater use of public healthcare services (pediatric care, vaccinations, screenings).

Based on an analysis of expenditure by households with dependent children in 2023, three household groups were identified, differing in terms of disposable income, spending levels across specific healthcare categories, and demographic structure. Group I, comprising 68% of the analyzed sample, recorded the lowest spending across all healthcare categories. This may indicate financial constraints within the group, driven by lower disposable income and a higher number of dependent children compared to the other clusters. Furthermore, location—particularly in rural areas—

may limit access to healthcare-related goods and services. This group also showed the lowest proportion of individuals with higher education, a factor potentially linked to lower health awareness and a reduced propensity to utilize private medical services.

Group II, comprising 27% of the households, was characterized by health expenditure levels that were higher than those in Cluster I but lower than in Cluster III (with the exception of sanatorium and hospital services, which were highest in this group). As in the other clusters, these households primarily utilized pharmaceutical products and medical services. They were located mainly in rural areas but also in towns with populations of 20,000–99,000. These households had average disposable incomes, suggesting that incomes higher than those in Cluster I may facilitate greater investment in health-related goods and services.

Cluster III was distinguished by the highest level of health-related spending—particularly on pharmaceuticals, which accounted for 72% of total health expenditure—as well as by the highest disposable income. Households in this group often had one dependent child, and the heads of these households held higher levels of education, a factor that may contribute to greater health awareness. Furthermore, higher income translates into a greater capacity to meet health-related needs.

The analysis also revealed that the level of education significantly influences the expenditure of households with dependent children. Higher education was associated with higher healthcare spending. The household's location is also worth noting; the majority of households in Group I resided in rural areas or smaller towns—a factor that may limit access to healthcare goods and services compared to households in larger cities. Conversely, Group III was heavily represented in large cities, which may have contributed to higher healthcare spending. These findings align with the research of M. Piekut [2025], who indicated that expenditure patterns vary across households, with income level, education, and household location being among the key determinants.

Furthermore, the number of dependent children also influences the level of health-related expenditure. In Group I—where households with two dependent children and large families were most common—health expenditure was lowest; conversely, in Group III, where households with one dependent child predominated, such expenditure was highest.

The results show that the vast majority of the surveyed households incur relatively low health-related expenses and exhibit a modest pattern of health consumption, limiting spending to basic health needs. Understanding the differences between households is crucial for effectively designing social policies and support programs aimed at improving the quality of life for families with children by increasing their access to health-related goods and services. The analysis makes it possible to identify the households most at risk of limited access to healthcare—those requiring special support. The health status of children and parents affects education, labor market

participation, and the future economic potential of society; therefore, the analysis of inequalities in health spending has long-term implications.

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TECHNICAL CONDITIONS OF DWELLINGS AND THE ENERGY COST BURDEN OF HOUSEHOLDS IN POLAND

***Marlena Piekut*[16], *Kamil Piekut*[17]**

Streszczenie

Celem artykułu jest ocena wpływu warunków technicznych mieszkań na obciążenie gospodarstw domowych kosztami energii w Polsce. Badanie oparto na danych z Badania Budżetów Gospodarstw Domowych GUS. Zastosowano analizę opisową oraz nieparametryczne testy statystyczne. Wyniki wskazują, że gospodarstwa domowe zamieszkujące lokale o gorszym stanie technicznym częściej przeznaczają większą część dochodu na energię i są bardziej narażone na ubóstwo energetyczne. Jednocześnie siła zależności okazała się relatywnie niewielka, co sugeruje, że obciążenie kosztami energii jest determinowane również przez inne czynniki społeczno-ekonomiczne. Uzyskane wyniki podkreślają znaczenie poprawy efektywności energetycznej budynków w ograniczaniu skutków kryzysu energetycznego i poprawie jakości życia gospodarstw domowych.

Key words: gospodarstwa domowe, ubóstwo energetyczne, wydatki na energię, warunki mieszkaniowe, kryzys energetyczny.

Summary

The aim of the article is to assess the impact of housing technical conditions on the energy cost burden of households in Poland. The study is based on data from the Household Budget Survey conducted by Statistics Poland. Descriptive analysis and non-parametric statistical tests were used. The results indicate that households living in dwellings with poorer technical conditions allocate a larger share of their income to energy expenditures and are more exposed to energy poverty. At the same time, the strength of the relationship proved relatively weak, suggesting that the energy cost burden is also shaped by other socio-economic factors. The findings highlight the importance of improving the energy efficiency of residential buildings in mitigating the effects of the energy crisis and enhancing household quality of life.

Key words: households, energy poverty, energy expenditure, housing conditions, energy crisis.

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Introduction

Rising energy costs have become one of the most significant socio-economic challenges facing contemporary households. In recent years, this issue has gained particular importance due to the energy crisis, increasing energy prices, and the ongoing energy transition. High energy expenditures may constrain households' ability to satisfy other consumption needs and, in extreme cases, contribute to the emergence of energy poverty. Therefore, analysing the factors affecting household energy expenditures constitutes an important area of economic and social research.

Previous studies indicate that the level of household energy expenditure is determined by a combination of economic and demographic factors as well as the characteristics of the housing stock [Besagni and Borgarello, 2018; Chen et al., 2022; Fuerst et al., 2020; Longhi, 2015; Mori and Yépez-García, 2017; Son and Yoon, 2020]. Particular attention has been paid to household income, household size, place of residence, the type of energy sources used, and building characteristics. Increasing emphasis has also been placed on the role of building energy efficiency, the quality of thermal insulation, and the technical condition of dwellings. Draughty windows, damp walls, inefficient heating systems, and structural deficiencies may result in higher energy consumption and, consequently, increase the energy costs borne by households.

In the existing literature, the technical condition of buildings is recognised as one of the key determinants contributing to energy poverty [del Rio et al., 2025; Szczygieł et al., 2024; Boemi et al., 2017]. Households occupying energy-inefficient dwellings frequently incur higher heating costs and face greater expenses in maintaining adequate thermal comfort, while simultaneously having limited financial capacity to undertake renovation and energy-efficiency improvements. This problem particularly affects low-income households, older people, and residents of rural areas, where the housing stock is generally older and characterised by lower technical standards.

In Poland, the relationship between housing conditions and the household energy cost burden is of particular relevance due to the relatively high proportion of residential buildings constructed before the introduction of modern energy-efficiency standards. Despite numerous thermal retrofitting programmes and policy measures aimed at improving the energy performance of residential buildings, a substantial share of households continues to occupy dwellings requiring renovation or modernisation [Szymańska et al., 2022; Szamrej-Baran, 2017; Sokołowski et al., 2020].

The aim of this study is to assess the impact of the technical condition of dwellings on the energy cost burden of households in Poland. The analysis is based on data from the Household Budget Survey conducted by Statistics Poland (Główny Urząd Statystyczny, GUS). The study examines both the long-term evolution of household

energy expenditures over the period 2004–2024 and the relationship between the technical condition of dwellings and the share of energy expenditures in households' disposable income in 2024.

The study adopts the research hypothesis that the deterioration of the technical condition of a dwelling increases the household energy cost burden and raises the risk of energy poverty. Verifying this hypothesis contributes to a better understanding of the role of housing conditions as one of the factors shaping the economic situation of households and may provide evidence to support the design of policies aimed at improving the energy efficiency of the residential housing stock.

1. Data and Research Methodology

The study is based on data obtained from the Household Budget Survey (HBS) conducted by Statistics Poland (Główny Urząd Statystyczny, GUS). The long-term analysis covers the period 2004–2024 and is based on aggregated data published by Statistics Poland concerning household income and expenditure. Detailed analyses of the relationship between the technical condition of dwellings and the household energy cost burden were carried out using the 2024 HBS microdata covering 28,349 households.

For the purposes of this study, household energy expenditure includes spending on electricity, natural gas, and other energy carriers used by households. To assess the household energy cost burden, three indicators were employed:

- the share of energy expenditure in household disposable income (%);
- the indicator of exceeding the 10% energy expenditure threshold (0 = no, 1 = yes);
- the share of housing maintenance costs in household disposable income (%).

The principal explanatory variable was the Poor Dwelling Technical Condition Index. The index was constructed as the sum of seven binary variables describing the occurrence of technical deficiencies in the dwelling or the residential building. The following characteristics were included:

- inadequate technical and sanitary conditions;
- malfunctioning heating system;
- leaking roof;
- poor technical condition of windows or floors;
- damp walls, floors, or foundations;
- insufficient heating during the winter season;
- inadequate thermal comfort during the summer.

The index ranged from 0 to 7, where a value of 0 indicated the absence of any technical deficiencies, while a value of 7 indicated the simultaneous occurrence of all

analysed problems. Owing to the relatively small number of households in the highest index categories, three groups were distinguished for comparative analyses: households with no technical problems (0), households with one technical problem (1), and households with two or more technical problems (2–7).

In the first stage of the analysis, descriptive statistics were used to examine changes in household income, consumption expenditure, and energy expenditure over the period 2004–2024. Subsequently, the distribution of households according to the level of the Poor Dwelling Technical Condition Index and selected socio-economic characteristics was analysed. These characteristics included disposable income, the number of unemployed household members, the number of household members with disabilities, the age and educational attainment of the household reference person, and the place of residence.

Given the asymmetric distribution of the analysed variables and the presence of outliers, non-parametric statistical methods were applied to assess differences between household groups. The statistical significance of differences between groups was evaluated using the Kruskal–Wallis test. In addition, the median test was employed to assess differences in the frequency of observations exceeding the median value of the analysed indicators. Statistical significance was determined at the $\alpha = 0.05$ level.

To assess the practical significance of the findings, the effect size coefficient ε^2 (epsilon squared) was calculated. This measure enabled an evaluation of the strength of the relationship between the technical condition of dwellings and the household burden associated with energy and housing maintenance costs.

2. Results

2.1. Characteristics of Household Energy Expenditure in Poland, 2004–2024

Between 2004 and 2024, average household disposable income per capita increased from PLN 735.4 to PLN 2,678.3, representing more than a 3.6-fold increase. During the same period, average consumption expenditure per capita rose from PLN 665.63 to PLN 1,814.37, corresponding to an almost 2.7-fold increase. Energy expenditure per capita increased from PLN 70.23 to PLN 187.90, representing an increase of more than 2.5 times.

An analysis of the relationship between household energy expenditure and disposable income indicates a substantial improvement in households' economic situation over the study period. Between 2004 and 2013, the share of energy expenditure in disposable income remained relatively stable at approximately 9–10%, reaching its highest level of 10.3% in 2006. In the following years, this indicator declined steadily, reaching 6.5% in 2020, reflecting the fact that household income

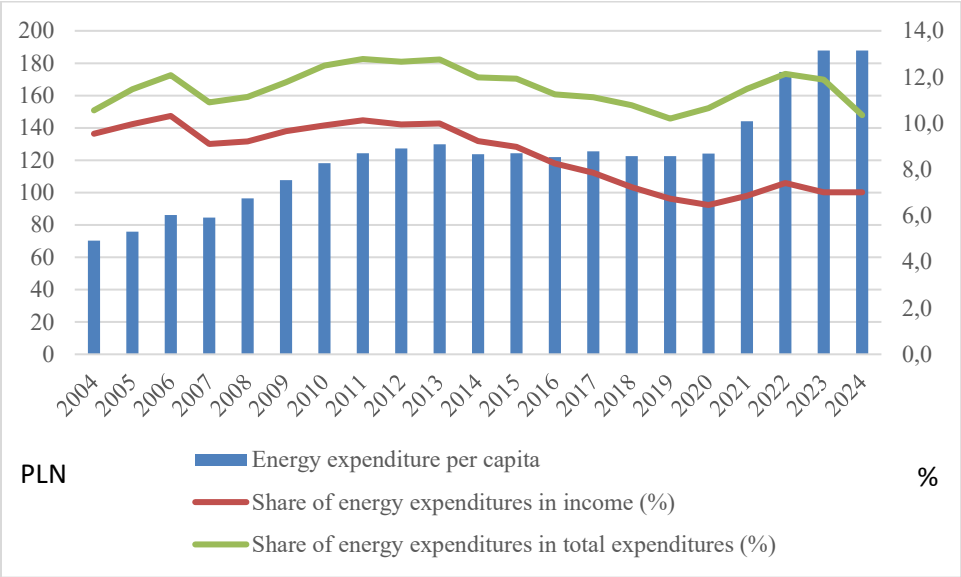
grew faster than energy expenditure. In 2021–2022, the share of energy expenditure increased again, reaching 7.4%, which can be attributed to the energy crisis and the sharp rise in energy prices. In 2023 and 2024, the indicator stabilised at approximately 7%.

A similar pattern can be observed for the share of energy expenditure in total household consumption expenditure. During the first decade of the twenty-first century, energy expenditure accounted for more than 12% of total consumption expenditure, reaching a maximum of 12.8% in 2011 and again in 2013. Subsequently, this share gradually declined to 10.2% in 2019. During the energy crisis, it increased once more, reaching 12.1% in 2022, before falling to 10.4% in 2024.

These findings indicate that, despite the substantial increase in nominal household energy expenditure, its relative importance within household budgets has declined over the long term. This suggests that the growth in household income outpaced the increase in energy costs. At the same time, the temporary increase in the share of energy expenditure observed in 2021–2022 highlights households' vulnerability to energy price shocks.

From the perspective of the subsequent analysis, it is particularly important to examine whether households occupying dwellings with poorer technical conditions—such as draughty windows, damp walls, or malfunctioning heating systems—incur higher energy expenditure and allocate a larger proportion of their disposable income to energy than households living in dwellings with better technical characteristics. In this context, the share of energy expenditure in disposable income may be regarded as a measure of the household energy cost burden and an indirect indicator of the risk of energy poverty.

Graph 1. Trends in Household Energy Expenditure and Energy Cost Burden in Poland, 2004–2024



Source: Authors' own elaboration based on data from the Household Budget Survey (HBS) conducted by Statistics Poland (GUS), 2024.

2.2. Distribution of the Poor Dwelling Technical Condition Index

In the next stage of the analysis, the Poor Dwelling Technical Condition Index was constructed. The index was defined as the sum of seven binary indicators representing technical deficiencies of the dwelling or the residential building, including a leaking roof, damp walls, the poor condition of windows and floors, and a malfunctioning heating system. The index ranged from 0 to 7, with higher values indicating a greater number of reported technical deficiencies.

Table 1. Distribution of Households by the Housing Technical Conditions Index in Poland, 2024

Housing technical conditions index	Number of households	Percentage of households
0	26 501	93,48
1	919	3,24
2	494	1,74
3	170	0,60
4	124	0,44

5	71	0,25
6	44	0,16
7	26	0,09
Razem	28 349	100,00

Source: Authors' own elaboration based on data from the Household Budget Survey (HBS) conducted by Statistics Poland (GUS), 2024.

The vast majority of households (93.5%) reported no technical deficiencies in their dwelling or residential building. Only 6.5% of households reported at least one technical problem, while the simultaneous occurrence of multiple technical deficiencies was relatively rare. An index value of 3 or higher was recorded for fewer than 1.5% of the surveyed households.

The analysis of households' socio-economic characteristics indicates that an increasing number of technical deficiencies is associated with a deterioration in households' economic situation. Most notably, a clear decline is observed in average monthly disposable income per capita. Among households reporting no technical problems, the average disposable income amounted to PLN 3,506.9 per capita per month, whereas for households with six or seven technical deficiencies, the corresponding figures were PLN 2,266.5 and PLN 2,309.6, respectively. This represents a difference exceeding 34%.

As the value of the index increases, so does the average number of unemployed household members and household members with disabilities. Among households without technical deficiencies, the average number of unemployed persons was 0.06, while for households with an index value of 4 it increased to 0.23. Similarly, the average number of household members with disabilities increased from 0.16 to more than 0.45 in households with the highest index values.

A clear relationship is also observed between the age of the household reference person and the technical condition of the dwelling. In households characterised by the largest number of technical deficiencies, the average age of the household reference person exceeded 60 years, compared with approximately 55 years for the entire study population.

The spatial analysis reveals considerable differences in the technical condition of dwellings between urban and rural areas. Among households reporting five technical deficiencies, as many as 53.5% were located in rural areas, while for households reporting six deficiencies, this proportion increased to 61.4%. By comparison, among households reporting no technical deficiencies, rural households accounted for 39.3% of the sample. These findings may reflect the older housing stock and the slower pace of residential building modernisation in rural areas.

A strong relationship is also evident between the educational attainment of the household reference person and the technical condition of the dwelling. Among households reporting no technical deficiencies, individuals with tertiary education (Bachelor's, Master's, or doctoral degree) accounted for more than 31% of household reference persons. However, this proportion declined systematically as the number of technical deficiencies increased. Households with the highest index values were predominantly represented by individuals with primary or basic vocational education. For example, among households reporting five technical deficiencies, as many as 60.6% of household reference persons had completed basic vocational education, whereas only approximately 4% had attained tertiary education. These findings suggest that lower levels of human capital may limit households' capacity to undertake renovations and improve the technical and energy performance of their dwellings.

2.3. The Technical Condition of Dwellings and the Household Burden of Energy and Housing Costs

In the next stage of the analysis, to increase the size of the comparison groups and reduce the problem of the limited number of observations in the highest index categories, households were classified into three groups:

- households reporting no technical deficiencies (index = 0);
- households reporting one technical deficiency (index = 1);
- households reporting two or more technical deficiencies (index ≥ 2).

The results indicate a clear relationship between the technical condition of dwellings and the household energy cost burden. The highest average share of energy expenditure in household disposable income was observed among households reporting two or more technical deficiencies (15.14%), whereas the corresponding figure for households reporting no technical deficiencies was 12.97%. These findings indicate that households occupying dwellings in poorer technical condition allocate a relatively larger proportion of their disposable income to meeting their energy costs.

Table 2. Kruskal–Wallis Test Results for Household Energy and Housing Cost Burden by Housing Technical Conditions

Housing Technical Conditions Index	Share of Energy Expenditure in Disposable Income	Energy Expenditure Above 10% of Disposable Income	Share of Housing Maintenance Costs in Disposable Income
0 problems	13866,8	13891,8	13829,2
1 problem	14685,2	14210,6	15498,3
≥2 problems	15078,4	14831,0	15352,8

Source: Authors' own elaboration based on data from the Household Budget Survey (HBS) conducted by Statistics Poland (GUS), 2024.

The Kruskal–Wallis test revealed statistically significant differences in the share of energy expenditure in household disposable income across households differing in the technical condition of their dwellings ($H = 28.19$; $p < 0.001$). The increasing mean rank values indicate a systematic rise in the household energy cost burden as housing conditions deteriorate. The lowest mean rank was observed among households reporting no technical deficiencies (mean rank = 13,866.8), whereas the highest was recorded for households reporting two or more technical deficiencies (mean rank = 15,078.4). These findings indicate that households occupying dwellings in poorer technical condition allocate a relatively larger proportion of their disposable income to energy expenditure.

The median share of energy expenditure in disposable income was 6.19%. Among households reporting two or more technical deficiencies, the number of households exceeding the median was higher than expected under the assumption of independence (505 observed versus 458 expected). In contrast, among households reporting no technical deficiencies, the number of households exceeding the median was lower than expected. This finding confirms that the deterioration of dwelling technical conditions is associated with a higher relative energy cost burden (median test: $\chi^2 = 19.77$; $p < 0.001$).

The analysis also revealed statistically significant differences in the frequency with which household energy expenditure exceeded 10% of disposable income (Kruskal–Wallis test: $H = 22.10$; $p < 0.001$). As the number of technical deficiencies increased, so did the probability of exceeding the 10% threshold, which is widely recognised in the literature as one of the indicators of the risk of energy poverty. Among households reporting two or more technical deficiencies, the number of cases exceeding the 10% threshold was 59 higher than expected (median test: $\chi^2 = 22.10$; $p < 0.001$). This indicates that poor dwelling conditions increase the likelihood of an excessive household energy cost burden.

Turning to the relationship between the technical condition of dwellings and the burden of housing costs, the average share of housing maintenance costs in disposable income amounted to 22.13% among households reporting no technical deficiencies, compared with 24.00% among households reporting two or more technical deficiencies. This increase may indicate that deteriorating dwelling conditions generate additional operating costs associated with heating, maintaining adequate indoor thermal comfort, and the need for more frequent repairs.

An interesting finding concerns households reporting only one technical deficiency. In this group, both the share of energy expenditure in disposable income (10.57%) and the housing cost burden (20.14%) were lower than among households reporting no technical deficiencies. This may suggest that isolated technical deficiencies do not necessarily translate into a deterioration of a household's economic situation, whereas a noticeable increase in costs emerges only when several technical problems occur simultaneously. These findings support the research hypothesis that the deterioration of dwelling technical conditions increases the household burden associated with both energy expenditure and housing maintenance costs.

The results of the Kruskal–Wallis test ($H = 66.83$; $p < 0.001$) indicate a strong association between the technical condition of dwellings and the housing cost burden. Households reporting technical deficiencies exhibited substantially higher mean ranks than households reporting no housing-related problems, indicating that housing maintenance costs constitute a greater economic burden for these households. It is noteworthy that even the occurrence of a single technical deficiency was associated with a statistically significant increase in the housing cost burden.

The median share of housing maintenance costs in disposable income was 11.18%. In the groups of households reporting technical deficiencies, the number of households exceeding the median was substantially higher than would be expected under the assumption of independence between the analysed variables (median test: $\chi^2 = 52.26$; $p < 0.001$).

Overall, the results of the non-parametric analyses indicate that poorer dwelling technical conditions are associated with a higher household burden of both energy and housing maintenance costs. Households reporting technical deficiencies were more likely to allocate an above-average share of their disposable income to energy expenditure and more frequently exceeded the 10% disposable income threshold commonly used as an indicator of the risk of energy poverty. These findings support the hypothesis that housing conditions constitute an important determinant of the household energy cost burden.

It should be noted, however, that although the differences between household groups distinguished by the technical condition of their dwellings were statistically significant ($p < 0.001$), the corresponding ε^2 (epsilon squared) effect size values were very small (0.0007–0.0023), indicating a weak association. This suggests that, while

poor dwelling conditions contribute to a higher burden of energy and housing maintenance costs, their effect is relatively limited compared with other economic and demographic determinants of household expenditure.

3.Disscusion

The findings confirm that the technical condition of dwellings is one of the factors associated with the household energy cost burden. Households occupying dwellings characterised by a greater number of technical deficiencies allocated a larger share of their disposable income to energy expenditure and were more likely to exceed the 10% threshold of disposable income spent on energy, which is widely used as one of the indicators of the risk of energy poverty. These findings are consistent with the theoretical framework suggesting that poor technical and energy performance of buildings increases the amount of energy required to maintain adequate living conditions [Kolokotsa and Santamouris, 2015; Vijayan et al., 2021; Spiru and Simona, 2017].

The analyses also demonstrate that technical deficiencies are not randomly distributed across households but are concentrated among those experiencing less favourable socio-economic conditions. Households reporting a greater number of technical problems were characterised by lower disposable incomes, a higher number of unemployed household members, a greater prevalence of household members with disabilities, and were more frequently located in rural areas. These findings are consistent with previous studies documenting the accumulation of multiple forms of material deprivation, whereby poorer housing conditions coexist with lower levels of household economic resources [Dewilde, 2021; Kennedy and Winston, 2019; Hick et al., 2022; Ayala et al., 2022].

A particularly noteworthy finding is that the highest levels of the household energy cost burden were observed primarily among households reporting the simultaneous occurrence of several technical deficiencies. This suggests that isolated technical shortcomings may not substantially affect household energy costs, whereas the accumulation of multiple deficiencies considerably reduces the energy performance of dwellings. This result is consistent with the approach adopted in the energy poverty literature, which emphasises the cumulative effect of multiple risk factors, including low income, poor building energy performance, and high energy prices [Teixeira et al., 2024; Matos et al., 2022; Ugarte et al., 2016].

At the same time, the results indicate that the influence of dwelling technical conditions on the household energy cost burden remains relatively limited. Although the observed relationships were statistically significant, the ε^2 (epsilon squared) effect size values were very small. This suggests that the technical condition of dwellings explains only a small proportion of the variation in household energy expenditure.

Consequently, household energy costs appear to be determined by a much broader set of factors than housing quality alone [Fuerst et al., 2020; Chen et al., 2022; Taneja and Mandys, 2022].

Other household characteristics are likely to play a more substantial role, including income level, household size, dwelling floor area, building type, heating source, and geographical location. In practice, households living in dwellings of comparable technical quality may incur considerably different energy expenditures depending on occupants' lifestyles, consumption behaviour, and financial capacity. This indicates that the relationship between housing conditions and household energy costs is multidimensional and should be analysed within a broader socio-economic context [del Rio et al., 2025].

The results also highlight the need to give particular attention to rural areas in policies aimed at improving the energy efficiency of residential buildings. The accumulation of technical deficiencies was observed more frequently among rural households. This may reflect both the larger share of older housing stock in rural areas and the more limited financial capacity of residents to undertake renovation and thermal retrofitting projects [D'Oca et al., 2018; Danusevics et al., 2023; Verma and Taegen, 2021]. Consequently, policies supporting building renovation and thermal retrofitting may generate not only energy and environmental benefits but also important social benefits through reducing the risk of energy poverty.

The study is subject to several limitations. First, the analysis is based on cross-sectional data, and part of the information regarding housing conditions relies on respondents' subjective assessments. Second, the database does not include information on the actual energy characteristics of buildings, such as the thermal insulation standard or heated floor area. These factors may substantially affect household energy consumption and should therefore be incorporated into future research.

Despite these limitations, the findings confirm that the technical condition of dwellings constitutes an important component of households' energy situation. Therefore, policies aimed at reducing energy poverty should not be limited solely to income support or compensatory measures. They should also include interventions designed to improve the technical quality of the residential housing stock and enhance the energy efficiency of residential buildings.

Conclusion

The findings indicate that the household energy cost burden should be analysed not only from an economic perspective but also within broader social and organisational contexts. In the face of contemporary energy, inflationary, and social crises, the quality of the residential housing stock has become an important determinant of both households' economic security and the quality of life. This is

particularly evident among households in disadvantaged socio-economic circumstances, where the accumulation of technical deficiencies in dwellings coincides with lower incomes, unemployment, and the presence of household members with disabilities.

The results confirm that poor dwelling conditions increase the risk of an excessive household energy cost burden and contribute to the occurrence of energy poverty. At the same time, the analysis demonstrates that these relationships are multidimensional and that the technical condition of dwellings explains only part of the variation in households' energy situation. These findings highlight the need for an integrated public policy approach that combines income-support measures with investments aimed at improving the energy efficiency of residential buildings.

The study further demonstrates that effective mitigation of the consequences of the energy crisis requires close cooperation among public institutions, local governments, and organisations responsible for housing and social policy. Modernisation measures focused on improving the technical quality of dwellings can reduce the risk of energy exclusion, strengthen households' resilience to energy price shocks, and ultimately contribute to improving societal well-being and quality of life.

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FROM DIGITALIZATION TO ECONOMIC WELFARE: A PANEL DATA ANALYSIS FROM THE PERSPECTIVE OF DIGITAL EMPLOYMENT

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Streszczenie

Niniejsze badanie analizuje związek między cyfryzacją a dobrobytem ekonomicznym poprzez zatrudnienie w sektorze ICT i produktywność. W analizie wykorzystano dane z 23 krajów Unii Europejskiej z lat 2017–2023 oraz zastosowano metody panelowe drugiej generacji, estymację efektów stałych z błędami standardowymi Driscolla–Kraaya oraz procedury bootstrap. Wyniki wskazują na dodatnie i statystycznie istotne zależności między cyfryzacją a zatrudnieniem w sektorze ICT, zatrudnieniem w sektorze ICT a produktywnością oraz produktywnością a dobrobytem ekonomicznym. Wyniki bootstrapu na poziomie krajów potwierdzają również istotny sekwencyjny związek pośredni między tymi zmiennymi. Ogólnie rzecz biorąc, badanie przedstawia zintegrowaną perspektywę na rolę zatrudnienia cyfrowego i produktywności w zrozumieniu szerszych ekonomicznych konsekwencji cyfryzacji.
Słowa kluczowe: cyfryzacja, zatrudnienie w ICT, produktywność, dobrobyt ekonomiczny, analiza danych panelowych.

Summary

This study examines the relationship between digitalization and economic welfare through ICT employment and productivity. Using data from 23 European Union countries for 2017–2023, the analysis applies second-generation panel data methods, fixed-effects estimation with Driscoll–Kraay standard errors, and bootstrap procedures. The results show positive and statistically significant associations between digitalization and ICT employment, ICT employment and productivity, and productivity and economic welfare. Country-level bootstrap findings also confirm a significant sequential indirect association among these variables. Overall, the study provides an integrated perspective on the role of digital employment and productivity in understanding the broader economic implications of digitalization.
Keywords: Digitalization, ICT Employment, Economic Welfare, Panel Data Analysis

JEL: O33, J24, C33

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Introduction

Digitalization has become one of the key driving forces of economic and social transformation alongside the Fourth Industrial Revolution. The widespread adoption of ICT—such as the Internet of Things, big data, cloud computing, and artificial intelligence—is reshaping production processes, business models, and service delivery, and is viewed not merely as technological renewal but as a multidimensional transformation of economic activity, offering new opportunities in innovation, productivity, competitiveness, digital skills, and digital employment [Bondarenko and Aleshkocski, 2019; Yoo and Yi, 2022; Kaggwa et al., 2023; Al-Kasasbeh, 2024]. The literature debates whether this transformation strengthens social protection or creates new labor-market vulnerabilities [Busemeyer et al., 2022]. Syarova [2020] highlights this duality, noting that the digital economy simultaneously raises structural unemployment and demand for highly skilled labor, while Vyshnevskyi et al. [2020] find that digitalization investment accelerates economic growth.

Khan et al. [2015] similarly link digitalization to long-term economic growth, associating high ICT investment with higher per-capita GDP, reduced unemployment, and improved quality of life, while noting that digital transformation requires time and resources. Consistent with this, Hernandez et al. [2016] show marked cross-country disparities in technology adoption—with less than 20% of firms in developed countries using cloud computing and about 15% using e-commerce—underscoring uneven digital development globally. As digitalization advances, its labor-market effects have become more visible [Hao et al., 2023]; Crisan et al. [2023] find higher youth employment in more digitalized EU countries but rising youth unemployment elsewhere, pointing to a risk of widening cross-national inequality, while De Groen et al. [2017] note that digitalization increases labor-market flexibility but also introduces new uncertainties around job security and social protection. More broadly, digital technologies are accelerating the emergence of new occupations and increasing demand for digital competencies [Autor, 2015; Goos et al., 2009].

Beyond these effects, digitalization is reshaping employment structures more directly. Wu and Yang [2022] find a shift of the workforce toward high-technology, high-skill sectors, while Zhao and Said [2023] show that the digital economy expands service-sector employment at the expense of traditional industry. Several studies report positive links between digitalization, employment, and growth: Bogoslov et al. [2022] find a strong positive relationship between digitalization and employment rates across EU countries, Mourou [2026] estimates that a 1% increase in the DESI index raises GDP growth by 0.3838%, and Qi and Chu [2022] argue that the digital economy supports growth through productivity gains and structural transformation. At the same time, digitalization affects public policy and work structures more broadly, enhancing productivity and public-service efficiency while also generating new forms of work and deepening existing inequalities [Maire, 2019; Nazarova et al., 2024], which

underscores the need to assess its economic and social effects within a balanced policy framework.

This study examines the relationship between digitalization and economic welfare within a sequential framework involving ICT employment and productivity. Its contribution lies in extending the digitalization–economic performance literature—which largely focuses on the direct link between digitalization and growth or productivity—by incorporating ICT employment and jointly examining these sequential relationships within an integrated framework. Data from 23 European Union countries for 2017–2023 were analyzed using second-generation panel data methods and bootstrap analysis.

4. Data and Methodology

In this study, the relationship between digitalization and economic welfare is examined using panel data analysis within a sequential empirical framework involving ICT employment and productivity. The analysis utilizes annual data from 23 European Union countries for the period 2017–2023. The level of digitalization is represented by the DESI index, economic welfare by the purchasing power standard (PPS), employment in the ICT sector by the ICTEMP variable, and productivity by the PROD variable. Information regarding the variables used in the analysis is presented in Table 1.

Since the official value of the DESI index for 2023 is not available, the value for that year was constructed by the authors as a synthetic indicator calculated as the arithmetic mean of the sub-indicators[20] comprising the index, without applying the original DESI weighting system. Additionally, to ensure data continuity, the analysis was limited to the 23 European Union countries[21] for which complete data on the relevant indicators were available.

[20] High-capacity network coverage, fiber infrastructure penetration, 5G coverage, digital density index, cloud computing and big data usage, adoption of artificial intelligence, digital skills, the share of ICT professionals in total employment, and digital public services.

[21] Belgium, Bulgaria, Austria, Croatia, Cyprus, Czechia, Denmark, Estonia, France, Germany, Greece, Ireland, Latvia, Lithuania, Poland, Portugal, Romania, Slovenia, Slovakia, Spain, Sweden, the Netherlands, and Luxembourg. Finland, Hungary, Italy, and Malta were excluded from the analysis due to missing data for one or more of the variables over the 2017–2023 study period.

Table 1. Variables Used in the Analysis

Variables	Description	Period, Type,Value	Source
DESI	Digital Economy and Society Index	Annual, Index Value	European Commission
DESI[2023]	Digital Economy and Society Index	Annual, Index Value	Author-constructed digitalization index (Eurostat)
ICTEMP	Information and Communication Technology Employment	Annual, Index Value	Eurostat
PROD	Labor Productivity	Annual, Index Value	Eurostat
PPS	Purchasing Power Standard	Annual, Index Value	Eurostat

Source: Created by the authors

Econometric Methodology

The econometric analysis proceeded in stages. Cross-sectional dependence was tested using Pesaran's [2004] CD test, stationarity using Pesaran's [2007] CIPS test, and slope homogeneity using Pesaran and Yamagata's [2008] Delta test. The relationships among the variables were estimated with fixed-effects models using Driscoll–Kraay standard errors, while wild cluster and country-level bootstrap procedures were used as complementary analyses.

Cross-Sectional Dependence Test

Cross-sectional dependence may arise when common economic or technological developments affect multiple panel units, potentially biasing conventional panel estimates. Therefore, this study tests cross-sectional dependence using Pesaran's [2004] CD test, which is based on the average correlation among panel-unit error terms and is applicable to both N>T and T>N panels. The test statistic is expressed as follows:

$$CD = \sqrt{\frac{2T}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij} \quad 1)$$

The hypotheses for the test were formulated as follows:

H_0:There is no cross-sectional dependence
H_1: Cross-sectional dependence exists

Panel Unit Root Test

In panel data analysis, the stationarity levels of the series were examined using the Pesaran [2007] CIPS panel unit root test, which accounts for cross-sectional dependence. The test is based on an extended Dickey–Fuller (CADF) regression that includes cross-sectional means and is expressed as follows:

$$\Delta y_{it} = \alpha_i + \beta_i y_{i,t-1} + \gamma_i \bar{y}_{t-1} + \delta_i \Delta \bar{y}_t + \varepsilon_{it} \quad (7)$$

Here, y_it denotes the relevant variable, y¯_t the panel mean, Δ the first-difference operator, α_i the constant term, and ε_it the error term. The CADF test statistic is obtained for each cross-sectional unit through this regression.

The general unit root test statistic for the panel is calculated by taking the average of the CADF statistics computed for each cross-sectional unit, as follows [Pesaran, 2007]:

$$CIPS = \frac{1}{N} \sum_{i=1}^{N} CAD\ F_i \quad (8)$$

The hypotheses formulated for this test are as follows:

$$H_0: \beta_i = 0 (\text{The series contains a unit root}) \quad (9)$$
$$H_1: \beta_i < 0 (\text{The series is stationary}) \quad (10)$$

Slope Homogeneity Test

In panel data analysis, determining whether slope coefficients are homogeneous across countries plays a critical role in identifying the appropriate econometric approach. In this study, a homogeneity test based on the Delta (Δ) statistic proposed by Pesaran and Yamagata [2008] was applied to test whether the coefficients in the models are equally distributed across units. This test examines whether the slope coefficients in the panel data model are constant across cross-sectional units. The relevant panel data equation can be expressed as follows:

$$y_{it} = \alpha_i + \beta_i' x_{it} + \varepsilon_{it} \quad (2)$$

Here, $i = 1,2, \dots, N$denotes the cross-sectional units and $t = 1,2, \dots, T$represents the time dimension. The homogeneity of the slope coefficients is tested within the framework of the following hypotheses [Pesaran and Yamagata, 2008]:

$$H_0: \beta_i = \beta \quad (3)$$

$$H_1: \beta_i \neq \beta_j \quad (4)$$

The statistical representation of the Delta test proposed by M. Hashem Pesaran and Takashi Yamagata (2008) is expressed as follows:

$$\tilde{\Delta} = \frac{\sqrt{N}\left(\frac{S}{N} - k\right)}{\sqrt{2k}} \quad (5)$$

Under the null hypothesis, this test statistic follows a standard normal distribution:

$$\widetilde{\Delta} \sim N(0,1) \tag{6}$$

Driscoll–Kraay Fixed Effects

Cross-sectional dependence, heteroskedasticity, and autocorrelation may lead to unreliable standard errors in conventional fixed-effects models. Therefore, this study employs the Driscoll–Kraay [1998] approach, which provides standard errors robust to these forms of dependence. The fixed-effects panel model is expressed as follows:

In this study, the panel data model with estimated fixed effects is generally expressed as follows:

$$y_{it} = \alpha_i + \beta_1 X_{1it} + \beta_2 X_{2it} + \cdots + \beta_k X_{kit} + \varepsilon_{it} \tag{11}$$

Here, $i = 1,2,\ldots,N$denotes the cross-sectional units (countries), $t = 1,2,\ldots,T$represents the time dimension, $\alpha_i$refers to unit-specific fixed effects, β_k indicates the slope coefficients, and ε_{it} denotes the error term. The Driscoll–Kraay approach adjusts standard errors for heteroskedasticity, autocorrelation, and cross-sectional dependence. Accordingly, all models were estimated using fixed effects with Driscoll–Kraay standard errors, and the results are presented model by model.

Wild Cluster Bootstrap

Given the short time dimension of the panel (T = 7) and the limited number of country clusters, the robustness of the baseline Driscoll–Kraay results was additionally assessed using a wild cluster bootstrap procedure. Wild cluster bootstrap inference is particularly useful in settings with a limited number of clusters, where conventional asymptotic inference may be less reliable [Cameron et al., 2008; Cameron and Miller, 2015]. Accordingly, the procedure was implemented with clustering at the country level and 9,999 replications using the wild bootstrap-t approach [Roodman et al., 2019].

Country-Level Bootstrap Procedure for the Sequential Indirect Statistical Association

Bootstrap is a nonparametric resampling method used to obtain coefficient estimates and confidence intervals [Efron, 1979; Efron and Tibshirani, 1994]. The resampling process is expressed as follows:

$$X^* = (x_1^*, x_2^*, \ldots, x_n^*) \tag{12}$$

Here, X^*represents the bootstrap sample obtained from the original sample. To preserve the panel structure, resampling was conducted at the country level rather than the individual observation level, with each country panel treated as a unit. The procedure used 9,999 replications, and the sequential indirect statistical association was calculated as the product of the estimated path coefficients [Preacher and Hayes, 2008]. Inference was based on percentile and bias-corrected 95% bootstrap confidence intervals. The estimate is interpreted as an indirect statistical association rather than a causally identified mediation mechanism.

5. Empirical Results

This section presents the empirical findings from the preliminary panel tests, fixed-effects estimations, and complementary bootstrap analyses.

Preliminary Test Results

The preliminary analysis examines cross-sectional dependence, slope homogeneity, and the stationarity properties of the variables.

Table 2. Cross-Sectional Dependence Test Results for the Variables

Variables	**PPS**	**ICTEMP**	**PROD**	**DESI**
Pesaran CD	2.51	33.84	20.55	40.50
Probability Value	0.012	0.000	0.000	0.000
Decision	H_0 Reject	H_0 Reject	H_0 Reject	Reject H_0

Source: Created by the authors

The findings presented in Table 2 indicate that cross-sectional dependence is statistically significant across all variables used in the analysis. The results suggest the presence of common economic and technological shocks among the countries in the sample. In particular, the high CD statistics for the DESI and ICTEMP variables reveal that digitalization processes and employment in information and communication technologies are influenced by similar dynamics across countries. Consequently, in the subsequent stages of the analysis, second-generation panel data tests that account for cross-sectional dependence and estimation methods based on Driscoll–Kraay standard errors were preferred.

The homogeneity test results obtained in this study are presented in Table 3.

Table 3. Model-Based Homogeneity Test Results

Dep. Variables	Delta	Prob. Value	Adj. Delta	Adj. Prob. Value	Result	Decision
Model 1	6.761	0.000	8.945	0.000	Heterogeneous	Reject H_0
Model 2	6.476	0.000	8.567	0.000	Heterogeneous	Reject H_0
Model 3	2.621	0.009	3.468	0.001	Heterogeneous	Reject H_0

Source: Created by the authors

H_0: The slope coefficients are homogeneous.

H_1: The slope coefficients are heterogeneous.

An examination of the homogeneity test results presented in Table 3 reveals that the Delta and Adjusted Delta test statistics are statistically significant for all models. Since the p-values are below the 5% significance level, the null hypothesis is rejected for all models, and it is concluded that the slope coefficients are heterogeneous. This finding indicates that the relationship between the variables in the model varies across countries. Consequently, it is understood that the coefficients are not constant due to differences in the economic and digital structures of the countries comprising the panel.

If the CIPS statistic obtained from the test is less than the critical values, the null hypothesis is rejected, and it is concluded that the series is stationary. The results of the CIPS panel unit root test applied in this study are presented in Table 4.

Table 4. Pesaran (2007) CIPS Panel Unit Root Test Results

Variables	Level CIPS (t-bar)	First Difference CIPS (t-bar)	p-value (Level)	p-value (First Difference)	Conclusion
DESI	-1.760	-1.886	0.401	0.242	H_0 Accepted
ICTEMP	-1.995	-1.701	0.138	0.485	H_0 Accepted
PROD	-3.286	-2.761	0.000	0.000	H_0 Rejected
PPS	-1.955	-2.658	0.172	0.000	H_0 Rejected

Source: Created by the authors

Table 4 shows that the variables exhibit different stationarity properties. PROD is stationary at level, whereas PPS becomes stationary after first differencing. In contrast, the unit root null cannot be rejected for DESI and ICTEMP. Given the short time dimension of the panel (T = 7), these results should be interpreted cautiously. Therefore, the subsequent analysis relies on fixed-effects models with Driscoll–Kraay standard errors, taking into account the previously identified cross-sectional dependence.

Driscoll–Kraay Fixed Effects Estimation Results

Model 1 Estimation Results

In this section, the relationship between digitalization and employment in the information and communication technology sector is examined using a fixed-effects panel data model with Driscoll–Kraay standard errors. This model examines the relationship between digitalization (DESI) and ICT-sector employment (ICTEMP), specified as follows:

$$ICTEMP_{it} = \alpha_i + \beta_1 DESI_{it} + \varepsilon_{it}$$

H_1: Digitalisation is positively associated with employment in the information and communication technology sector

Table 5. Model 1 Driscoll–Kraay Fixed Effects Estimation Results

Driscoll–Kraay standard error regression					Method: Fixed Effects Regression	
Number of Observations : 161					Number of Groups: 23	
Group variable (i): country_id					F(1, 6) = 49.75	
R_2= 0.2823					Probability > F = 0.0004	
ICTEMP	Coefficient	Driscoll–Kraay Std. Error	t-Statistic	P>|t|	95% Confidence Interval	
DESI	3.712	0.526	7.05	0.000	2.424	5.000
_cons	135.510	24.070	5.63	0.001	76.611	194.408

Source: Created by the authors

As shown in Table 5, DESI is positively and significantly associated with ICTEMP ($\beta = 3.712$, $p < 0.01$; Prob > F = 0.0004; $R^2 = 0.2823$), supporting H1: higher digitalization is associated with greater ICT-sector employment. Overall, the findings are consistent with a positive association between digitalization and digital labor capacity.

2.2.1 Model 2 Estimation Results

This model examines the relationship between ICT-sector employment (ICTEMP) and productivity (PROD), specified as follows:

$$PROD_{it} = \alpha_i + \beta_1 ICTEMP_{it} + \varepsilon_{it}$$

H_2: Employment in the information and communication technology sector is positively associated with productivity.

Table 6. Model 2 Driscoll–Kraay Fixed Effects Estimation Results

Driscoll–Kraay standard error regression					Method: Fixed Effects Regression	
Number of Observations:161					Number of Groups: 23	
Group variable (i): country_id					F(1, 6) = 107.55	
R_2= 0.0457					Probability > F = 0.000	
PROD	Coefficient	Driscoll–Kraay Std. Error	t-Statistic	P>|t|	95% Confidence Interval	
ICTEMP	0.018	0.001	10.37	0.000	0.014	0.028
_cons	102.940	1.873	54.96	0.000	98.357	107.524

Source: Created by the authors

As shown in Table 6, ICTEMP is positively and significantly associated with PROD ($\beta = 0.018$, $p < 0.01$; Prob > F = 0.000; $R^2 = 0.046$), supporting H2, though the coefficient magnitude is modest. Overall, the findings are consistent with of a positive association between digital labor and productivity.

2.2.2 Model 3 Estimation Results

This model examines the relationship between productivity (PROD) and economic welfare, measured by GDP per capita in purchasing power standards (PPS), specified as follows:

$$PPS_{it} = \alpha_i + \beta_1 PROD_{it} + \varepsilon_{it}$$

H_3: Productivity is positively associated with economic welfare.

Table 7. Model 3 Driscoll–Kraay Fixed Effects Estimation Results

Driscoll–Kraay standard error regression					Method: Fixed Effects Regression	
Number of Observations:161					Number of Groups: 23	
Group variable (i): country_id					F(1, 6) = 429.95	
R_2= 0.5061					Probability > F = 0.000	
PPS	Coefficient	Driscoll–Kraay Std. Error	t-Statistic	P>|t|	95% Confidence Interval	
PROD	0.696	0.033	20.74	0.000	0.614	0.778
_cons	25.688	4.004	6.42	0.001	15.890	35.487

Source: Created by the authors

As shown in Table 7, PROD is positively and significantly associated with PPS ($\beta = 0.696$, $p < 0.01$; Prob > F = 0.000; $R^2 = 0.506$), supporting H3 with relatively high explanatory power. Overall, the findings provide empirical evidence of a positive association between productivity and economic welfare.

Robustness Analysis: Wild Cluster Bootstrap Results

H_4: Digitalisation is positively associated with economic welfare through ICT employment and productivity.

Table 8. Wild Cluster Bootstrap Robustness Results

Model	Coefficient	Driscol Kraay p-value	Wild Bootstrap p-value	Robustness
Model 1	3.712	0.001	0.001	Supported
Model 2	0.018	0.001	0.0308	Supported
Model 3	0.697	0.001	0.0002	Supported

All three baseline associations remain statistically significant under wild cluster bootstrap inference (DESI–ICTEMP: $p < 0.001$; ICTEMP–PROD: $p = 0.0308$; PROD–PPS: $p = 0.0002$), supporting the robustness of the results despite the panel's short time dimension.

Bootstrap Results for the Sequential Indirect Statistical Association

H_4: Digitalisation is positively associated with economic welfare through ICT employment and productivity.

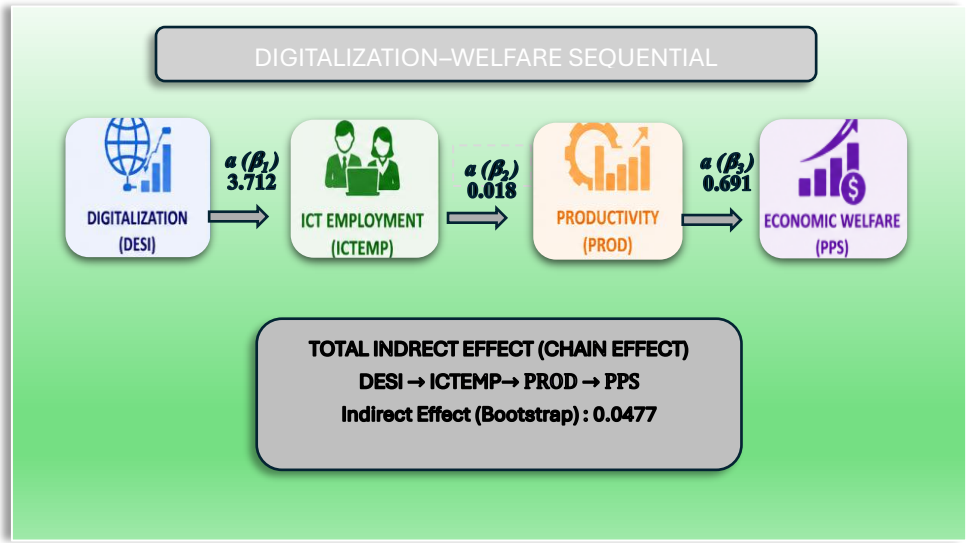
Table 9. Bootstrap Results for the Sequential Indirect Statistical Association

Association	Coefficient	Bootstrap Std. Error	Percentile 95% CI	Bias-Corrected 95% CI	Conclusion
DESI → ICTEMP → PROD → PPS	0.0477	0.0364	[0.0142, 0.1498]	[0.0139, 0.1454]	Significant

Source: Created by the authors

Using the country-level bootstrap procedure (Section 1.1.6) with 9,999 replications, the estimated coefficient was 0.0477 (SE = 0.0364), with both the percentile (0.0142, 0.1498) and bias-corrected (0.0139, 0.1454) 95% CIs excluding zero. These results support H4, indicating a significant sequential indirect statistical association — rather than a causally identified mechanism — among digitalization, ICT employment, productivity, and economic welfare.

Figure 1. Digitalization–Welfare Sequential Framework



Source: Created by the authors

6. Discussion

The findings indicate positive associations among digitalization, ICT employment, productivity, and economic welfare. These results are consistent with previous studies linking digitalization with employment and economic performance [Bogoslov et al., 2022; Crisan et al., 2023; Qi and Chu, 2022]. Unlike studies focusing mainly on the direct digitalization–growth relationship, this study jointly considers ICT employment, productivity, and economic welfare within a sequential empirical framework. The bootstrap findings further support a significant indirect statistical association among these variables, although this relationship should not be interpreted as a causally identified mechanism.

7. Conclusions

This study examined the relationship between digitalization and economic welfare using data from 23 EU countries for 2017–2023. The results show positive associations between digitalization and ICT employment, ICT employment and productivity, and productivity and economic welfare. The country-level bootstrap analysis also supports a significant sequential indirect statistical association. By incorporating ICT employment into the digitalization–economic performance relationship, the study provides an integrated perspective on digital employment, productivity, and welfare.

The findings should nevertheless be interpreted cautiously. The short time dimension of the panel (T = 7), the restriction of the sample to EU countries, and potential endogeneity and reverse causality limit causal interpretation and generalizability. Future research may employ longer time periods, broader samples, additional control variables, and alternative identification strategies.

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COMMUTING SAFETY AS A NEW DIMENSION OF ORGANISATIONAL RESPONSIBILITY TOWARDS EMPLOYEES

Agata Jaździk-Osmólska[22]

Streszczenie

Celem rozdziału jest przedstawienie bezpieczeństwa dojazdów do pracy jako wyłaniającego się obszaru odpowiedzialności organizacji wobec pracownika oraz zaproponowanie konstruktu klimatu bezpieczeństwa dojazdów do pracy (CSC). Rozdział łączy syntezę literatury dotyczącej klimatu bezpieczeństwa, psychospołecznego klimatu bezpieczeństwa i transferu norm poza miejsce pracy z wynikami badania własnego przeprowadzonego na reprezentatywnej próbie dorosłych Polaków. Wyniki wskazują na realność ryzyka drogowego w codziennej mobilności, dominację samochodu prywatnego oraz niską widoczność działań pracodawców, co uzasadnia potrzebę dalszych badań nad CSC.

Słowa kluczowe: bezpieczeństwo dojazdów do pracy, klimat bezpieczeństwa, psychospołeczny klimat bezpieczeństwa, odpowiedzialność organizacji, dobrostan pracowników, mobilność pracownicza

Summary

The chapter conceptualises commuting safety as an emerging dimension of organisational responsibility towards employees and proposes Commuting Safety Climate (CSC) as a domain-specific construct. It combines a synthesis of literature on safety climate, psychosocial safety climate and the transfer of safety norms beyond the workplace with findings from a representative study of adult Poles. The findings indicate that commuting-related road risk is socially relevant, that private car use remains dominant, and that employer actions supporting safer commuting are weakly visible, thereby justifying further research on CSC.

Keywords: commuting safety, safety climate, psychosocial safety climate, organisational responsibility, employee well-being, employee mobility

JEL: J28, M14, I31, R41, O15.

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Introduction

Employee safety is usually analysed within the boundaries of the organisation: in relation to the workstation, occupational health and safety procedures, training, the reporting of unsafe events and the employer's formal duties [Hu et al., 2025; Sankar et al., 2023]. Increasingly, however, this framing is not sufficient to describe the real conditions of work-related safety. Contemporary organisations shape not only what employees do at work, but also the rhythm of their day, time pressure, the possibility of flexible work, levels of fatigue, psychosocial well-being and how professional duties are reconciled with everyday life [Dera, Adedokun & Iyiola, 2025; Lintanga & Rathakrishnan, 2024; Liu et al., 2025]. Daily commuting is one area in which this relationship becomes particularly visible.

Commuting is formally located outside the workplace and is often treated as a private choice made by the employee [Mazumdar et al., 2025a]. From a management perspective, however, it is far from neutral. Employees commute at a particular time, influenced by work schedules, supervisors' expectations, norms of punctuality, access to remote work, flexibility in working time, and their material circumstances. The organisation may therefore co-create conditions in which a safe journey to work is more or less likely [Hubert et al., 2025; Liu et al., 2025].

This chapter aims to present commuting safety as a new dimension of organisational responsibility towards employees and to propose the construct of Commuting Safety Climate (CSC). The chapter is conceptual and empirical in character. It brings together conclusions from a review of recent research on organisational safety climate, psychosocial safety climate, and the transfer of safety norms beyond the workplace, with findings from an exploratory study on commuting safety in Poland conducted in 2025.

The guiding question of the chapter is whether employee safety ends when the employee leaves the workplace, or whether the organisation can indirectly influence the safety of daily commuting through norms, organisational culture, support, communication, flexibility, and the reduction of time pressure. The proposed answer is a new construct that enables the description of the organisational dimension of employees' everyday mobility.

1. Organisational safety climate and the boundaries of the workplace

Contemporary literature suggests that organisational safety climate may be understood as employees' collective perception of organisational priorities, norms, and practices related to safety that influence their everyday behaviour [Bafail & Alamoudi, 2025; Hu et al., 2025; Sankar et al., 2023]. In other words, safety climate is the signal perceived by employees about the real value an organisation attaches to

safety in practice: in decisions, communication, procedures, supervisory behaviour and the allocation of resources [Bafail & Alamoudi, 2025; Ishii, Fujitani & Matsushita, 2024; Mearns & Flin, 1999; Sankar et al., 2023].

A review of recent research from 2023-2025 suggests that the field of safety climate research is moving away from simple models explaining the direct effect of safety climate on employees' safety behaviour and towards more mechanistic models. Increasingly, studies examine not only the associations between safety climate and employee behaviour, but also the intermediate mechanisms and organisational conditions that strengthen or weaken these relationships. Research points to the roles of safety motivation, emotional exhaustion, co-worker support, organisational identification, safety leadership, and organisational learning [Dera, Adedokun & Iyiola, 2025; Ishii, Fujitani & Matsushita, 2024; Liu et al., 2025].

The development of psychosocial safety climate (PSC) is especially important for the present chapter. PSC extends the understanding of safety beyond physical hazards and links it to wellbeing, mental health, emotional exhaustion, job satisfaction, engagement and the quality of work relationships [Dera, Adedokun & Iyiola, 2025; Lintanga & Rathakrishnan, 2024; Nguyen et al., 2025]. This approach is highly relevant to the analysis of commuting, because road risk associated with employees' daily mobility does not arise solely in the transport environment. It may be reinforced by organisational and psychosocial factors such as time pressure, work overload, fatigue, emotional exhaustion, low control over working time and a lack of organisational flexibility.

A second strand that is particularly important for conceptualising commuting safety climate is the spillover perspective, which assumes that experiences, norms, demands and resources can be transferred between different domains of an individual's life. In classic accounts of the work-life interface, spillover means that work conditions, strains, resources and behavioural patterns can affect functioning outside work [Edwards & Rothbard, 2000; Grzywacz & Marks, 2000]. In the context of safety, this implies that safety norms and priorities established within an organisation may be internalised by employees and carried over into behaviour outside the formal work setting. This view is consistent with the safety climate literature, in which safety climate is linked to safety behaviour through knowledge, motivation and leadership [Christian et al., 2009; Griffin & Neal, 2000; Neal & Griffin, 2006], and with research on safety leadership, which demonstrates the importance of inspiring, monitoring and learning for different forms of safety behaviour [Griffin & Hu, 2013]. The closest empirical precedent for this logic is the study by Hubert, Abdel Hadi and Roswag (2025), which shows that perceived COVID-19 safety climate may be associated with employees' safety behaviour in their personal lives, particularly when organisational identification is strong [Hubert et al., 2025]. In this sense, Commuting Safety Climate may be interpreted as an extension of safety climate, reflecting the spillover of safety norms from the organisation into employees' everyday mobility.

From the perspective of commuting safety, the key gap is therefore not a lack of knowledge about safety climate as such. Rather, the gap lies in the weak connection between this body of knowledge and research on employees' everyday mobility, especially in non-transport organisations. The literature includes studies of safety behaviour at work, PSC, leadership and well-being, as well as studies of commuting modes, comfort, accessibility and transport choices [Mazumdar et al., 2025b]. What is still missing are studies that treat commuting as a domain of organisational safety climate.

2. Methodology

The empirical basis of the chapter is the author's own study, "Commuting Safety in Poland 2025", carried out as an online CAWI omnibus survey. The study was conducted between October and November 2025 on a representative sample of N = 1,000 adult residents of Poland aged 18 and over. Key socio-demographic and territorial characteristics weighted the sample to reflect the structure of Poland's adult population. Participation was voluntary and anonymous, and respondents completed the questionnaire independently through an online platform. The questionnaire included four main blocks of questions:

- experience of a road traffic incident;
- commuting to work;
- employer actions;
- perceived safety.

The first block concerned experiences of road traffic incidents while travelling to or from work or school in the preceding three years. Respondents indicated whether the incident concerned them personally, a family member or someone outside the family, and whether it was a collision or an accident involving injuries requiring medical treatment.

The second block concerned the dominant modes of everyday commuting, including walking, cycling, electric scooter use, public transport, private car use, company car use, employer-organised transport, and car sharing.

The third block concerned employer actions aimed at increasing the safety or comfort of commuting, such as subsidising public transport, organising employee transport, bicycle infrastructure, flexible working hours or remote work, safety training and campaigns, and psychological support after a road traffic incident.

The fourth block measured perceived safety on the typical route to work or school, using a five-point scale ranging from "very unsafe" to "very safe".

In addition, basic socio-demographic variables were included: gender, age, education, voivodeship, employment status, size of place of residence and subjective assessment of material situation.

The analysis was descriptive and exploratory. In the first stage, basic descriptive statistics and response distributions were calculated for the main variables. Socio-demographic and territorial characteristics, including age, material situation, size of place of residence, and region, were then analysed. Further analysis examined relationships between commuting mode, declared experience of road traffic incidents, visibility of employer actions and perceived safety. Given the cross-sectional design of the study and the limited number of questions in the omnibus module, the findings should be interpreted as a basis for conceptualising the problem and formulating hypotheses for further research, rather than as evidence of causal relationships.

The strength of this approach lies in its ability to capture commuting safety in a broad population sample and to assess whether the issue is socially and organisationally visible.

The study is limited, however, by the absence of detailed measures of transport exposure, such as commuting distance, travel time, weekly commuting frequency, time of travel and perceived time pressure. It also did not include detailed organisational data, such as sector, company size, employment form, work model, the maturity of the occupational health and safety system, or formal mobility policies. These limitations indicate the direction for further research on Commuting Safety Climate, in which individual, organisational, and transport data will need to be combined.

3. Commuting as an area of risk and organisational gap

The findings show that road traffic risk is not a marginal issue. At least one experience of a road traffic incident - personal, family-related or involving someone outside the family - was reported by 27.4% of respondents. Personal involvement in a collision or accident was reported by 12.7% of respondents, while 4.0% reported an accident involving injuries requiring medical treatment. At the same time, everyday mobility related to work and education remains strongly car-oriented: the most frequently indicated commuting mode was driving a private car (44.5%).

Against this background, the organisational gap is particularly visible. Among those for whom the employer question was applicable, 45.4% reported no employer action supporting safer commuting. The most frequently perceived initiatives were indirect and organisational in nature: flexible working hours or the possibility of remote work (21.8%), occupational health and safety training or campaigns concerning mobility (17.0%), and encouragement to car share (13.5%). This means that, for a substantial proportion of employees, commuting safety remains outside the visible organisational agenda.

The result concerning subjective perceived safety is also noteworthy. Despite relatively high exposure to road traffic incidents, the mean assessment of the safety of the typical route to work or school was 3.84 on a scale from 1 to 5, with a median of

4. Around 70% of respondents chose “rather safe” or “very safe”. This may point to a normalisation of risk: everyday danger becomes embedded in routine and is not always interpreted as a problem requiring organisational action.

Comparative analyses also show that perceived safety is more strongly associated with subjective material situation than with urbanisation or region of residence. Respondents who assessed their material situation more positively reported a higher sense of safety in commuting. This may be interpreted as a signal that commuting safety has a resource dimension: it depends on the ability to choose the mode of transport, route, and time of travel, as well as on available alternatives and a sense of agency. Younger groups, in turn, more often reported personal experiences of road traffic incidents, suggesting the importance of lifestyle and mobility intensity.

Table 1. Selected findings from the study “Commuting Safety in Poland 2025”

Area	**Finding**	**Relevance for the CSC construct**
Contact with a road traffic incident	27.4% of respondents reported contact with a road traffic incident in the preceding three years; 12.7% reported personal experience; 4.0% reported an accident involving injuries.	Commuting is a real area of risk rather than a marginal private matter.
Dominant commuting mode	44.5% indicated the private car as driver.	Employees’ everyday mobility is strongly dependent on individual transport decisions.
Visibility of employer actions	45.4% of working respondents did not see any employer actions supporting safer commuting.	There is an organisational gap and low institutionalisation of the issue.
Perceived safety	Mean score 3.84/5; median 4; around 70% positive assessments.	Possible normalisation of risk and a discrepancy between exposure and perceived safety.
Differentiating factors	Perceived safety is differentiated mainly by material situation; exposure to incidents by age.	Commuting safety has a dimension of resources, agency and inequality.

Source: Author’s own elaboration based on the study “Commuting Safety in Poland 2025”.

The issue of employer actions also requires cautious interpretation. In larger urban centres, respondents more often reported multiple employer actions (2+). However, the effect was weak and does not support a simple conclusion that “cities act while other areas do not”. It is more likely that the visibility of actions depends on

organisational features such as size, the formalisation of HR and occupational health and safety practices, management culture, sector, work flexibility and the maturity of wellbeing policies. The key findings are presented in Table 1.

4. Commuting Safety Climate as a proposed new construct

The findings of the author's own study, together with the state of the literature, suggest a need for a construct that captures the organisational dimension of commuting safety. I propose defining this construct as the Commuting Safety Climate (CSC). It should not be understood as a new label for the general safety climate, but rather as an extension of it into the boundary zone between work and everyday life.

CSC may be provisionally defined as employees' shared perceptions of the extent to which an organisation recognises, communicates, supports, and learns about employees' everyday mobility safety. This definition emphasises four elements. First, CSC concerns employees' perceptions, that is, whether organisational actions and norms are visible and understandable to them. Second, it concerns commuting as a specific domain, distinct from workstation safety. Third, it includes both formal actions and informal organisational signals. Fourth, it assumes that the organisation can learn from employees' experiences, incidents and needs. The boundaries of the CSC construct are important because they prevent the concept from being overstretched. CSC does not imply that the organisation is fully responsible for all road traffic incidents, nor does it replace state transport policy, road infrastructure or the individual responsibility of road users. It does mean, however, that the organisation can create conditions that support safer commuting decisions or, conversely, reinforce risk factors such as time pressure, lack of flexibility, indifference to fatigue, or an absence of support after an incident.

A preliminary operationalisation of CSC may include four dimensions: visibility of the issue, norms and communication, organisational support, and organisational learning. The first refers to whether the organisation recognises the risk of commuting in its communication, HR, or occupational health and safety practices. The second concerns supervisors' language, punctuality norms and the absence of pressure to arrive "at any cost". The third covers flexible hours, remote work, transport-related support and assistance after a road traffic incident. The fourth is understood as the organisation's ability to use employees' experiences, incidents and near misses to modify work practices. Together, these dimensions capture whether commuting safety is present, credible and actionable within organisational culture.

5. Theoretical framework and mechanistic model of CSC

The proposed CSC construct needs to be grounded in a wider theoretical framework. This chapter adopts three complementary perspectives: (1) the capability

approach, (2) the perspective of cumulative disadvantage or cumulative inequality, and (3) spillover theory, supplemented by the literature on psychosocial safety climate, organisational safety climate and safety leadership. What these approaches have in common is that they move away from treating commuting as an isolated act of travel and instead recognise it as part of a broader employee experience shaped by resources, working conditions, organisational pressure, well-being, and the relationship between the individual and the organisation.

The capability approach makes it possible to view commuting safety not as a formal choice of transport mode, but as an employee's real capability to reach work safely. In Sen's approach, what matters is not merely freedom of choice but the actual range of opportunities that individuals can realise under specific social, economic, and organisational conditions [Sen, 1999; Nussbaum, 2011]. Employees may formally decide whether they commute by car, public transport, bicycle or on foot. Still, their ability to choose a safer form of commuting depends on material resources, time, access to alternative transport modes, work flexibility, agency, and organisational pressure. In this sense, commuting safety is not simply an individual preference or a private transport decision, but the outcome of the real opportunities available to the employee. The findings of the author's own study, in which perceived safety was associated with the assessment of material situation, support this interpretation. Commuting safety, therefore, has a resource component and may be unequally distributed across employee groups.

The perspective of cumulative disadvantage highlights the accumulation of seemingly individual burdens. Long commuting time, fatigue, stress, pressure to be punctual, low flexibility, lack of support after an incident and a weaker material situation may reinforce one another [Dannefer, 2003; Diprete & Eirich, 2005; Ferraro & Shippee, 2009]. As a result, commuting may become part of a wider mechanism that reduces well-being, increases the risk of absence and makes stable participation in work more difficult. This perspective allows commuting safety to be interpreted not only as a transport problem but also as a problem of unequal access to resources, time, flexibility, and organisational support.

Spillover theory, in turn, helps explain how organisational norms, demands, and resources may be transferred beyond the workplace. In classic accounts of the work-life interface, spillover refers to work conditions, strains, resources, and behavioural patterns affecting an individual's functioning outside work [Edwards & Rothbard, 2000; Greenhaus & Beutell, 1985; Grzywacz & Marks, 2000]. In relation to safety, this implies that safety norms established within the organisation may be internalised and carried over into behaviour outside the formal work setting. If an organisation communicates safety as a value, strengthens employees' identification with safety norms and reduces exhaustion, it may support safer behaviour beyond the workstation. Conversely, if it declares safety important but, in practice, reinforces time pressure,

rigidity, and a lack of understanding of commuting conditions, it may create an inconsistent climate in which formal safety messages lose credibility.

This perspective is complemented by psychosocial safety climate, which broadens the understanding of organisational safety beyond physical hazards and links it to well-being, mental health, emotional exhaustion, the quality of work relationships and employee engagement [Dera, Adedokun & Iyiola, 2025; Dollard & Bakker, 2010; Hall, Dollard & Coward, 2010; Lintanga & Rathakrishnan, 2024]. This is crucial for research on commuting because employees' everyday mobility is both a source of road traffic risk and a point at which the consequences of work-related stress, fatigue, time pressure, and limited control may become visible. The closest empirical precedent for the logic of safety-norm spillover beyond the workplace is the study by Hubert, Abdel Hadi and Roswag (2025), which indicates that perceived COVID-19 safety climate may be associated with employees' safety behaviour in their personal lives, particularly when organisational identification is strong [Hubert et al., 2025].

On this basis, the mechanistic model of CSC may be presented as a sequence of four levels: organisational practices and norms → perceived commuting safety climate → intermediate mechanisms → individual and organisational outcomes (Table 3).

Organisational practices include, among other things, flexible working hours, the possibility of remote work, communication about safe commuting, training, support after a road traffic incident, and everyday management norms, such as how delays caused by safety-related travel conditions are handled. Perceived CSC refers to whether employees see commuting as an area of genuine organisational concern, visible in communication, support, norms and learning.

Intermediate mechanisms may include perceived organisational responsibility, a sense of control over commuting, time pressure, fatigue, organisational identification, safety motivation, and trust in supervisors. CSC outcomes may be analysed at two levels. At the individual level, they include safer mobility practices, avoiding driving under time pressure, choosing less-risky times and routes, limiting mobile phone use while driving, and reporting hazards and perceived safety. At the organisational level, they may include absences, lateness, productivity loss, work disruption, costs of support after an incident, and other hidden organisational costs.

This approach has two advantages. First, it does not reduce CSC to a simple list of employer actions. Second, it makes it possible to distinguish between climate antecedents, climate dimensions, intermediate mechanisms and outcomes. For example, work flexibility may be both an organisational practice and a form of support. Still, its effect on safety may operate through reduced time pressure and an increased sense of control. Similarly, safety communication may be a dimension of CSC. Still, its effectiveness may depend on employees' identification with the

organisation, trust in supervisors, and consistency between formal messages and everyday management practice.

Table 3. Proposed logic of the mechanistic CSC model

Model level	Example variables	Role in the model	Example research question
Organisational practices and norms	flexible working hours, remote work, safety communication, training, post-incident support, punctuality norms, supervisors' responses to commuting difficulties	antecedents of CSC	Which practices and norms make commuting safety visible and organisationally significant?
Commuting Safety Climate	visibility of the issue, norms and communication, organisational support, organisational learning	central construct	Do employees perceive commuting as an area of genuine organisational concern?
Intermediate mechanisms	time pressure, fatigue, sense of control, perceived organisational responsibility, organisational identification, safety motivation, trust in supervisors	mediators/moderators	Through which mechanisms may CSC influence employees' mobility decisions and behaviour?
Individual and organisational outcomes	mobility behaviour, perceived safety, reporting of hazards, incidents, absence, lateness, productivity loss, hidden organisational costs	outcomes	Does CSC translate into safer mobility practices and reduced organisational costs and disruptions?

Source: Author's own elaboration.

6. Implications for management

From the perspective of management studies, commuting safety marks a shift from a reactive to a proactive understanding of organisational responsibility. In the reactive model, the organisation responds only after an incident, such as a collision, accident,

prolonged absence or employee crisis. In the proactive model, safety conditions are shaped in advance by reducing time pressure, supporting flexibility, recognising fatigue, developing mobility-related practices, and integrating commuting into wider well-being, HR, ESG, CSR, and risk management activities.

The findings suggest that organisations can influence commuting safety, but this influence is neither general nor automatic. What matters is not the sheer number of employer actions, but their visibility, consistency and relevance to employees' everyday commuting conditions. Flexible working hours and remote work may be particularly important because they increase employees' control over time and reduce exposure to unfavourable travel conditions. CSC is therefore useful as a diagnostic construct: it allows organisations to assess whether commuting safety is merely declared or genuinely embedded in everyday management practice.

Conclusion

Commuting safety is an important yet under-recognised area of research on organisational responsibility towards employees. The literature review suggests that safety climate is increasingly analysed not only as a predictor of workplace behaviour but also as an element of wider organisational culture, psychosocial well-being, identification, and the transfer of norms beyond the organisation's formal boundaries. At the same time, direct studies of the impact of organisational climate on commuting safety in non-transport organisations remain rare.

The findings of the exploratory study "Commuting Safety in Poland 2025" show that commuting is a real area of risk: a substantial proportion of respondents have experienced road traffic incidents, everyday mobility remains strongly car-oriented, and almost half of working respondents do not notice employer actions that support safer commuting. At the same time, high subjective perceived safety may indicate risk normalisation and insufficient visibility of the problem.

The proposed construct of Commuting Safety Climate (CSC) enables the capture of this area as a domain of organisational culture and shared responsibility. CSC does not remove the employee's individual responsibility, nor does it replace infrastructural and public measures for road safety. It does, however, indicate that the organisation can create conditions that make safer commuting decisions more likely. The most important research task now is to operationalise CSC and directly test its relationship with commuting behaviour, incidents, perceived safety, and absence and hidden organisational costs.

In a broader sense, a safe journey to work is not merely the employee's private matter. It reflects the quality of the relationship between the organisation and the employee. It tests whether safety is a real value in organisational culture or merely a formal element of risk management.

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WAR-INDUCED BRAIN DRAIN: ECONOMIC CONSEQUENCES OF HUMAN CAPITAL FLIGHT FROM UKRAINE (2022–2025)

***Tetiana Maslak*[23], *Magdalena Majchrzak*[24]**

Streszczenie
Artykuł analizuje zjawisko drenażu mózgów wywołanego konfliktem zbrojnym, ze szczególnym uwzględnieniem Ukrainy w latach 2022–2025. Na podstawie danych Organizacji Współpracy Gospodarczej i Rozwoju (OECD), Międzynarodowej Organizacji ds. Migracji (IOM) oraz Eurostatu autorzy identyfikują skalę, strukturę i makroekonomiczne konsekwencje masowej emigracji wysoko wykwalifikowanych pracowników z Ukrainy. Wyniki wskazują, że drenaż mózgów wywołany wojną stanowi odrębną kategorię analityczną, różniącą się od klasycznych modeli migracji ekonomicznej zarówno tempem, jak i strukturą demograficzną przepływów. Artykuł wskazuje na podwójny efekt: straty kapitału ludzkiego dla Ukrainy oraz wyzwania integracyjne dla krajów przyjmujących, w szczególności Polski, Niemiec i Czech. Wnioski mają implikacje dla polityki publicznej zarówno na poziomie krajowym, jak i unijnym.
Słowa kluczowe: drenaż mózgów, migracja przymusowa, kapitał ludzki, odbudowa postkonfliktowa, integracja na rynku pracy, ekonomia uchodźcza

Summary
The article examines the phenomenon of conflict-induced brain drain, with particular focus on Ukraine in the period 2022–2025. Drawing on data from the OECD, the International Organization for Migration (IOM), and Eurostat, the authors identify the scale, structure, and macroeconomic consequences of the mass emigration of highly qualified workers from Ukraine. The findings suggest that war-induced brain drain constitutes a distinct analytical category, differing from classical models of economic migration in both the pace and demographic composition of population flows. The article identifies a dual effect: human capital losses for Ukraine and integration challenges for receiving countries, particularly Poland, Germany, and the Czech Republic. The conclusions carry implications for public policy at both national and European Union levels.
Keywords: brain drain, forced migration, human capital, post-conflict reconstruction, labour market integration, refugee economics

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Introduction

The full-scale Russian invasion of Ukraine launched on 24 February 2022 triggered one of the largest and most rapid population displacements in post-World War II European history. Within the first three months of the conflict, over six million Ukrainians had registered for temporary protection in European Union member states [UNHCR 2022]. While the humanitarian dimensions of this crisis have been widely documented, the long-term economic consequences – and in particular the structural effects of mass emigration of human capital – remain insufficiently systematised in the academic literature.

The concept of brain drain, defined as the emigration of trained and talented individuals from a country of origin to another country [Docquier and Rapoport 2012: 681], has been studied extensively in the context of developing economies and post-communist transition states. However, conflict-induced brain drain presents a qualitatively distinct set of mechanisms, timescales, and demographic profiles that challenge the applicability of classical migration models. The Ukrainian case is particularly salient: it involves a middle-income country with a high level of educational attainment, a significant share of workers in technologically intensive sectors, and a receiving-country ecosystem – primarily Poland – that shares both linguistic proximity and deep historical labour migration ties [Górny and Kaczmarczyk 2018: 180].

This article advances three primary research objectives. First, to quantify the scale and qualitative composition of Ukrainian labour emigration in the period 2022–2025, distinguishing between temporary displacement and structural human capital loss. Second, to assess the macroeconomic consequences of this emigration for the Ukrainian economy, with particular attention to sectoral labour shortages, fiscal implications, and long-run growth potential. Third, to evaluate the dual effects of Ukrainian human capital inflows on receiving countries, examining both the economic benefits and integration challenges associated with large-scale labour market entry.

The article is structured as follows. Section 1 reviews the theoretical foundations of brain drain research and identifies the specific characteristics of conflict-induced emigration. Section 2 analyses the empirical data on Ukrainian emigration flows and their human capital composition. Section 3 examines the macroeconomic consequences for Ukraine. Section 4 addresses the effects on key receiving countries. Section 5 discusses policy implications and post-war reconstruction scenarios. Conclusions synthesise the findings and propose directions for future research.

1. Brain Drain in the Context of Armed Conflict: A Theoretical Framework

The economics of brain drain has evolved substantially since the pioneering contributions of Bhagwati and Hamada [1974], who modelled emigration of skilled workers as a source of welfare loss for the country of origin. Subsequent decades of research produced a more nuanced body of work, with the "new economics of brain drain" acknowledging that emigration can generate remittance flows, knowledge spillovers, and diaspora networks that may partially or fully offset the losses associated with human capital outflows [Docquier and Rapoport 2012: 700]. The concept of "brain gain" introduced by Mountford [1997: 289] suggested that when emigration prospects incentivise human capital formation domestically, the net effect on origin country welfare may even be positive.

However, the literature on brain gain and beneficial brain drain has been developed largely in the context of voluntary, predominantly economic migration from developing countries. Conflict-induced emigration constitutes a categorically different phenomenon along several dimensions. First, the speed of outflows is several orders of magnitude faster than in voluntary economic migration: in the Ukrainian case, flows that would ordinarily develop over years were compressed into weeks [IOM 2023: 12]. Second, the demographic composition of conflict refugees – predominantly women, children, and elderly, reflecting the wartime prohibition on male exit – deviates markedly from the male-dominated, working-age profile typical of labour migration. Third, the decision-making context is characterised by extreme uncertainty, which means that emigration decisions may be revised as the security situation evolves, complicating the distinction between temporary displacement and permanent relocation [Ruiz and Vargas-Silva 2013: 780].

Lee's push-pull framework [1966], while conceptually foundational, requires significant adaptation to capture conflict-driven mobility. The push factors in wartime emigration are not primarily economic (wage differentials, unemployment) but existential: physical insecurity, destruction of housing and infrastructure, disruption of education and healthcare. This distinction matters analytically because it implies that the mitigation of brain drain cannot rely exclusively on labour market instruments – wage increases, employment guarantees, or professional reintegration programmes – but must address the security preconditions of return [Black et al. 2006].

For the purposes of this article, we define war-induced brain drain as the permanent or semi-permanent emigration of individuals with tertiary education or specialised professional skills, driven primarily by armed conflict, with a statistically significant probability of non-return exceeding five years from the onset of displacement. This definition deliberately focuses on those with high human capital, since their departure generates disproportionate macroeconomic effects relative to their share of the

emigrant population, and since receiving countries exhibit systematically higher retention rates for skilled migrants [OECD 2023a: 28].

2. Scale and Structural Composition of Ukrainian Human Capital Emigration, 2022–2025

The quantitative analysis of Ukrainian emigration flows after February 2022 faces significant methodological challenges. Administrative data from receiving countries capture registrations for temporary protection but systematically undercount secondary mobility (movement between EU member states), informal labour market participation, and return migration. IOM survey data provide valuable complementary information but are subject to sampling constraints. With these limitations in mind, the following analysis draws on the best available combination of administrative, survey, and modelled data.

By the end of 2024, approximately 6.5 million Ukrainian citizens were registered as displaced persons in European countries, with Poland hosting the largest share (approximately 1.6 million registered, though estimates of actual presence range up to 2.0 million), followed by Germany (1.1 million), the Czech Republic (380,000), and Italy (210,000) [Eurostat 2025]. The total stock of Ukrainians abroad – including pre-war labour migrants – is estimated at between 8 and 9 million individuals, representing approximately 20–22 percent of Ukraine's pre-war population [IOM 2024: 5].

Of particular macroeconomic significance is the educational composition of this emigrant population. According to IOM household surveys conducted in 2023, approximately 43 percent of displaced Ukrainians aged 25–64 held tertiary education credentials, compared to a Ukrainian national average of 35 percent in the same age group [IOM 2023: 34]. This positive selection for education is consistent with patterns observed in other conflict-displacement episodes [Beine, Docquier and Rapoport 2008: 635] and reflects both the greater capacity of educated individuals to navigate administrative processes and the higher residential concentration of tertiary-educated workers in western and central Ukrainian cities that experienced lower direct destruction.

Sectoral analysis reveals particularly acute losses in several high-value-added segments of the labour market. The information technology sector, which had emerged as one of Ukraine's most dynamic and internationally competitive industries in the pre-war period – with revenues of approximately USD 7.3 billion in 2021 – experienced significant workforce emigration, with IT Ukraine Association estimating that approximately 30–35 percent of industry professionals worked from abroad by the end of 2022, though many remained employed by Ukrainian-registered companies [IT Ukraine Association 2023]. The healthcare sector registered losses of approximately 20,000 physicians and 50,000 nursing staff as of early 2024,

exacerbating pre-existing shortages in a country where the healthcare system was already under severe wartime strain [Ministry of Health of Ukraine 2024]. Engineering, scientific research, and higher education – sectors with high average human capital intensity and established international networks facilitating emigration – were also disproportionately affected.

A critical distinction for macroeconomic analysis is the differentiation between temporary displacement and structural human capital loss. Survey evidence suggests that return intentions are highly sensitive to three variables: current security conditions in Ukraine, the quality of labour market integration in the host country, and the presence of school-age children. Households with children enrolled in the host-country education system show significantly lower stated return probabilities [OECD 2023b: 41]. Among Ukrainians in Poland, where labour market integration has been comparatively rapid due to linguistic proximity and pre-existing migration networks, the share of respondents reporting "definite" or "likely" return fell from 68 percent in mid-2022 to 47 percent in late 2024 [Górny et al. 2024: 12]. This trajectory, if sustained, implies a structural human capital loss substantially larger than temporary displacement statistics suggest.

3. Macroeconomic Consequences for Ukraine

The macroeconomic consequences of war-induced brain drain for Ukraine operate through several interrelated channels: direct labour market contraction, fiscal pressure from reduced tax revenues and increased transfer payments, innovation and productivity losses from sectoral human capital depletion, and long-run demographic deterioration.

The labour market channel is the most immediate and quantitatively significant. Ukraine's active labour force contracted from approximately 17.2 million in early 2022 to an estimated 12.5–13.0 million by late 2024, reflecting the combined effects of emigration, military mobilisation, wartime mortality, and disability [World Bank 2024: 18]. Labour shortages are most severe in manufacturing, construction, healthcare, and agriculture – sectors essential to both wartime economic functioning and post-war reconstruction. Average wage growth in Ukraine has exceeded 30 percent in nominal terms over the period 2022–2024, reflecting tight labour supply rather than productivity gains, and is associated with inflationary pressure and competitiveness erosion in export sectors [National Bank of Ukraine 2025].

The fiscal consequences of brain drain are difficult to isolate from the broader macroeconomic disruptions of wartime, but can be partially estimated through a counterfactual approach. Pre-war analysis by Kupets [2012: 348] estimated the per-worker fiscal contribution of tertiary-educated Ukrainians at approximately twice the national average, reflecting higher wages, payroll tax compliance, and consumption expenditure. Applying this differential to conservative estimates of the emigration of

1.5 million tertiary-educated workers yields a gross fiscal loss – prior to any offset from remittances – of approximately USD 8–10 billion annually in foregone personal income tax, social contributions, and consumption-based revenues. This estimate, while subject to wide uncertainty bands, represents a non-trivial share of Ukraine's wartime fiscal gap, which has been financed primarily through international donor assistance [IMF 2025].

The innovation and productivity channel, while harder to quantify, may represent the most durable long-run consequence. Human capital is characterised by substantial complementarities: the departure of skilled workers reduces the productivity of remaining workers who depend on specialised knowledge networks, collaborative innovation ecosystems, and knowledge spillovers [Moretti 2004: 683]. Ukraine's pre-war emergence as a regional technology hub was predicated on precisely such agglomeration effects, and their partial dissolution may prove difficult to reconstitute even after security conditions improve. International experience from post-conflict reconstruction in Bosnia-Herzegovina, Kosovo, and Iraq suggests that highly skilled diaspora returnees are critical to economic revitalisation but that their return requires not only security but also institutional quality and economic opportunity that typically takes years to re-establish [Faist 2008: 22].

4. Impact on Receiving Countries: Opportunities and Integration Challenges

The mass inflow of Ukrainian human capital to EU receiving countries has generated a complex mix of economic benefits and structural challenges. The overall macroeconomic effect has been broadly positive for receiving economies in the short to medium term, particularly in labour-scarce segments of the market, but significant heterogeneity exists across countries, sectors, and time periods.

Poland, as the primary receiving country, offers the most instructive case study. Ukrainian workers contributed to alleviating structural labour shortages in construction, logistics, retail, and food processing that had been accumulating since Poland's own large-scale emigration to Western Europe following EU accession [Dustmann and Glitz 2011: 527]. Polish GDP growth in 2022–2023 was partially sustained by Ukrainian labour supply, with National Bank of Poland modelling suggesting a positive contribution of 0.3–0.5 percentage points to annual growth from Ukrainian labour market participation [NBP 2023: 7]. The fiscal balance of Ukrainian presence in Poland – accounting for tax revenues, social service costs, education expenditure for children, and housing market effects – has been assessed as broadly neutral to marginally positive in the short run, with uncertainty increasing over longer horizons as family benefit entitlements accumulate [Polish Economic Institute 2023: 15].

Germany's experience illustrates the integration challenges associated with large-scale inflows of highly qualified workers whose credentials require formal recognition. Despite their high average educational attainment, Ukrainian refugees in Germany faced significant barriers to professional qualification recognition, particularly in regulated professions such as medicine, law, and engineering. As of early 2024, approximately 45 percent of Ukrainian refugees in Germany with tertiary qualifications were employed in jobs below their qualification level [IAB 2024: 9]. This "brain waste" phenomenon – the systematic underutilisation of human capital due to institutional barriers – represents both a welfare loss for displaced individuals and an economic inefficiency for the receiving society.

The Czech Republic presents a distinct pattern characterised by particularly high labour market participation rates among Ukrainian refugees (approximately 57 percent of working-age Ukrainians were employed by mid-2023, the highest rate among major receiving countries) driven by a combination of liberal work authorisation policies, acute pre-existing labour shortages in manufacturing, and targeted employer integration programmes [Czech Statistical Office 2024]. However, the high employment rate has been accompanied by concerns about working conditions, wage discrimination, and limited access to language learning and upskilling opportunities.

5. Policy Implications and Post-War Reconstruction Scenarios

The policy implications of war-induced brain drain operate at three levels: the Ukrainian government, receiving-country governments, and the European Union as a supranational coordination framework. Effective policy responses require acknowledgment of the tension between two partially competing objectives: the short-run interest of receiving countries in retaining productive and fiscally contributing migrants, and the long-run interest of Ukraine (and arguably the EU as a whole) in the return of human capital essential to post-war reconstruction.

For Ukraine, the strategic priority must be the creation of conditions favourable to return migration of skilled workers. International experience consistently identifies security, economic opportunity, and institutional quality as the three primary determinants of return [Black et al. 2006]. While the first is a function of the military situation and international security guarantees, the latter two can be partially shaped by policy. The Marshall Plan model advanced by various analysts and international institutions [World Bank 2022: 3] – combining reconstruction investment with institutional reform and private sector development – offers a framework for creating labour market conditions attractive to returnees. Specific instruments should include competitive remuneration in rebuilt public institutions (particularly healthcare and education), streamlined credential recognition for diaspora returnees, and dedicated

reintegration support programmes targeting individuals with families in receiving countries.

For receiving-country governments, the principal challenge is designing policies that simultaneously support integration for those who will remain permanently and maintain open channels for voluntary return. Overly aggressive integration – including, for example, automatic conversion of temporary to permanent residence status – may reduce return probabilities. Conversely, precarious temporary status and barriers to professional recognition reduce productivity and welfare for those who remain. A "flexible status" model, in which individuals can transition between temporary and longer-term residence categories based on personal circumstances and evolving security conditions in Ukraine, offers a more adaptive policy framework [Ruiz and Vargas-Silva 2013: 782].

At the EU level, the Temporary Protection Directive – which has provided the legal framework for Ukrainian protection status since March 2022 – will require revision as its provisions approach their implementation limits. A durable EU framework for conflict-induced mass displacement should include provisions for skills matching and mutual recognition of qualifications, coordination of remittance facilitation to Ukraine, and co-financing of integration programmes in receiving member states with lower fiscal capacity. The macroeconomic case for such coordination is straightforward: brain waste in receiving countries and brain drain from Ukraine are jointly inefficient outcomes that coordinated policy can partially mitigate.

Conclusion

This article has examined war-induced brain drain from Ukraine in the period 2022–2025 as a phenomenon that requires a distinct analytical framework beyond the established literature on voluntary economic migration. The empirical evidence documents a positive selection of emigrants for human capital, concentration of losses in high-value-added sectors including information technology, healthcare, and engineering, and a declining trend in stated return intentions that suggests structural human capital losses are accumulating alongside temporary displacement.

The macroeconomic consequences for Ukraine are multidimensional: direct labour market contraction, fiscal revenue losses, innovation ecosystem disruption, and long-run demographic deterioration. For receiving countries, the net economic effect has been broadly positive in the short run, though qualified by brain waste phenomena, integration barriers, and distributional concerns. The dual nature of this phenomenon – simultaneously a loss for the origin country and a gain for receiving countries – places it at the centre of a coordination problem that national policies alone cannot adequately address.

Three principal conclusions emerge for policy. First, the return of skilled Ukrainian workers is a prerequisite for successful post-war reconstruction and cannot be

achieved through isolated Ukrainian government initiatives; it requires coordinated international support for economic recovery and institutional development. Second, receiving-country integration policies should be designed with explicit attention to their effects on return probabilities, avoiding path dependencies that permanently lock in displacement. Third, the EU requires a more flexible and comprehensive framework for managing conflict-induced mass displacement that balances the legitimate interests of receiving states, the welfare of displaced individuals, and the reconstruction needs of origin countries.

The limitations of this analysis reflect the inherent challenges of studying ongoing phenomena: data availability lags, uncertainty about future security trajectories, and the impossibility of disentangling war-induced from longer-run demographic trends in Ukrainian emigration. Future research should prioritise longitudinal tracking of individual migration trajectories, sectoral analyses of human capital depletion in Ukraine's key industries, and comparative studies of post-conflict brain drain recovery drawing on historical analogues. The Ukrainian case, as the largest conflict-induced displacement event in Europe since 1945, offers – at considerable human cost – an invaluable natural experiment for the economics of forced migration.

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APPLYING BEHAVIORAL FINANCE RESEARCH TO COUNTER WAR FATIGUE: INSIGHTS FROM THE RUSSO-UKRAINIAN CONFLICT

Tomasz Wyluda[25]

Streszczenie
W miarę jak konflikt rosyjsko-ukraiński wkracza w piąty rok, zmęczenie wojną osłabia poparcie społeczne. Artykuł bada nowatorskie zastosowanie błędów poznawczych z zakresu finansów behawioralnych do łagodzenia tego zjawiska w trzech grupach: wśród wojskowych, cywilów oraz sojuszników. Wykorzystując interdyscyplinarne podejście jakościowe, praca proponuje ukierunkowane strategie - m.in. obligacje wojenne, nadania ziemi czy redefinicję pomocy wojskowej - oparte na takich heurystykach, jak awersja do straty czy utopione koszty. Artykuł kończy się oceną etycznych implikacji tych narzędzi, dostarczając decydentom praktycznych ram działania i ostrzegając przed manipulacją.
Słowa kluczowe: Polityka publiczna, Wojna, Zmęczenie wojną, Finanse behawioralne

Summary
As the Russo-Ukrainian conflict enters its fifth year, war fatigue erodes public support. This paper explores the novel application of behavioral finance biases to mitigate this fatigue among three critical groups: Ukrainian military personnel, civilians, and international allies. Using an interdisciplinary qualitative approach, the study proposes targeted strategies—such as war bonds, land grants, and reframing military aid - based on cognitive biases like loss aversion and the sunk cost fallacy. The paper concludes by evaluating the ethical implications of these tools, offering a practical framework for policymakers while warning against manipulative practices.
Key words: Public Policy, War, War fatigue, behavioral finance

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Introduction

The Russo-Ukrainian War began in February of 2022. Russia's increasing aggression towards Ukraine produced a strong reaction from the international community. This motivated Ukraine to stand up for itself against a stronger enemy. Western countries' quick and proper support helped Ukraine gain its first successes. However, Ukrainian morale weakens as the war drags on, as highlighted by Bakke, Toal and O'Loughlin [2024]. According to the Economist Intelligence Unit [2024], the desire to fight is declining. This concept is known as war fatigue. War fatigue can be defined as a gradual decline in public support for a military conflict over time. Various elements may contribute to war fatigue, including increasing casualties, enemy disinformation campaigns, financial burden, and perception of no visible success on the front.

Western allies also experience the same war fatigue. Many nations are in the process of searching for the best way to help Kyiv financially. This assistance has been a hotly debated issue during the elections in many countries. Some politicians state that many resources should be reallocated to address the issues that affect the domestic audience. Surveys show that a large proportion of the public shares this view [Pew Research Center 2024]. In addition, there is increasing evidence that Russia deploys psychological tactics like disinformation [Coffey 2023] and propaganda [Sinovets and Shultz 2023] to impact the morale of Ukraine and NATO countries.

Managing behavioral factors in prolonged conflicts is essential for achieving victory. The crucial role of psychology in a wartime situation is seen in numerous instances, such as the war in Afghanistan (2001-2021). In Afghanistan, the US-led coalition possessed military superiority over the Taliban. However, as the conflict advanced, early support among the US public waned, while the will to fight among the Taliban remained. This contributed to the USA's withdrawal from Afghanistan.

There is extensive research on the application of psychology in the war context [Kellett 2013; Mackay and Tatham 2011], but this area has not been explored from a behavioral finance perspective. This paper aims to fill the research gap by examining psychological biases and cognitive errors in protracted armed conflict. This interdisciplinary study, therefore, seeks to examine the application of financial biases in light of the ongoing war between Ukraine and Russia. This research has practical applications. First, policymakers can develop strategies to increase the motivation and commitment of soldiers, civilians, and allies. Second, understanding behavioral biases can help to identify and counter adversary manipulations.

The paper consists of five sections. The first part, the literature review, evaluates psychological research in the context of warfare and delineates gaps in the existing literature. Next, the methodological section explicates potential behavioral biases that may be applicable in the context of war. The following results chapter elucidates the

nuanced application of the identified biases across distinct groups. The penultimate section discusses the limitations and ethical dilemmas of the research. The final section synthesizes the key findings and lists potential areas for further exploration.

1. Literature Review

War fatigue can be defined as a gradual erosion in public support for military efforts. This process occurs gradually and is visible in such aspects as reduced media coverage in mainstream news, decreased commitment from allied nations, dodging the draft, increased public support for compromises, negotiations with the aggressor, and even desertions from the military [Mueller 1973; Hallin 1986].

Historical examples suggest that war fatigue is a leading indicator that can help predict the outcome of a war. In World War I, for instance, the immense human and material losses contributed to the exhaustion and collapse of the German army [Watson 2008]. This forced decision-makers in the Central Powers to hastily end the war and accept unfavorable conditions of peace. Psychological factors are becoming increasingly important, especially in democratic societies, where voters can influence the decisions of politicians. This can be observed in more recent conflicts such as the Vietnam War, the Korean War, the Iraq War, and the War in Afghanistan. In all of those cases, prolonged conflict affected public opinion and pressured politicians to withdraw from the countries, in most cases not achieving strategic long-term objectives [Mueller 1973]. Even in authoritarian countries, public opinion also plays an important role. In the short term, dictators can suppress protests, but in the long term, public dissatisfaction can cause violent and rapid changes in regimes.

Gelpi, Feaver and Reifler [2009] found that support for war is based on society's perception of the possibility of victory and the importance of the cause. When the military effort is still in the initial stages, the level of public emotional commitment usually remains high, but as time passes, pressures for disengagement increase [Gartner and Segura 1998]. The leaders may portray the war as a way of preserving national honor and reputation, as the society expects, to sustain the people's support [Dafoe, Renshon and Huth 2014]. Emotions and cultural tendencies of society are the major factors that keep people motivated. These emotions can be accessed through propaganda or media campaigns. For instance, leaders may counteract the effects of fatigue to enhance the commitment to carry on with the war [Shimshoni 2022]. Insights from behavioral sciences facilitate the understanding of individual behavior in conflict operations. Military leaders can maintain combat motivation and social support by addressing elements such as morale, esprit de corps, and the psychological effects of war [Kellett 2013; Mackay and Tatham 2011]. Furthermore, military recruitment advertisements can use many psychological manipulations, such as a positive framing, presenting military service as an opportunity for personal growth

and patriotism - motivations well documented among American soldiers [Woodruff, Kelty and Segal 2006].

Clark [2024] suggests that resilience in the context of war can be explained by many factors, which can be observed on many levels, such as psychological, systemic, and national. All these factors are interrelated and can contribute to the attainment of political objectives. The analysis of resilience by levels shows how important it is to have a proper discourse about the war that shapes the international reaction and support from allies. Tomz and Weeks [2021] showed that relations with international partners are crucial for the allied societies' willingness to defend a partner country under attack. In his work, Liberman [2006] noted that retributive sentiments - the desire to punish an aggressor perceived as evil - may enhance the citizens' support for military action. Moreover, mass demonstrations of support for the conflict can affect public opinion through herd behavior [Banerjee 1992; Klandermans 1992].

Although the psychological aspects of conflict have been extensively studied, the subject is still relatively unexamined from the behavioral finance perspective (which integrates financial motivations and behavioral biases). Behavioral finance is a novel but rapidly growing field that can offer new perspectives and new tools to manage public support for the war. Traditional finance assumes that humans are rational, and their actions can be explained solely from the utilitarian point of view. Thus, many classical financial theories are based on the concept of Homo Oeconomicus - fully rational, perfectly informed, and unaffected by emotions. However, the new implications of psychology show that people are not entirely rational. Their cognitive capacity and psychological characteristics influence economic choices [Tversky and Kahneman 1974].

Cognitive and emotional biases explain many intriguing phenomena unexplained from the traditional finance perspectives. The research suggests that people generally make good decisions but sometimes make mistakes. Those mistakes are caused by heuristics, which are mental shortcuts [Kahneman and Tversky 1979]. Analyzing every minor decision in life is time-consuming and requires much energy (when measured in terms of calories); thus, it is inefficient. The human brain uses mental shortcuts to make fast, energy-efficient decisions in everyday life. However, this may lead to mistakes [Thaler 2016], though understanding these errors can help solve many problems [Kahneman 2011].

Psychology research shows that social norms and group dynamics influence individual decision-making during crises [Cialdini 2009]. Many financial mistakes are observed when people face war. Szkutnik and Wyluda [2022] observed that investment in war bonds is highly inefficient, and the purchase of war bonds cannot be explained solely from the rational economic man perspective. There is a patriotic demand that makes people behave irrationally from a financial standpoint. The war

bonds utilize the sunk cost fallacy in which people are willing to invest more and are emotionally engaged when they invest their savings [Arkes and Blumer 1985].

Despite these findings, there is a lack of research on the methodological use of behavioral biases in finance to address war fatigue, particularly in the Ukraine crisis. This paper addresses this problem by identifying significant biases and proposing ways to implement them ethically.

2. Methodology

This study applies qualitative research to investigate cognitive errors and emotional biases during wartime. In this part of the paper, we identify and present the biases that can be utilized in the war context. These biases can then be used to analyze the potential solutions for the problems that caused the war fatigue in the Russo-Ukrainian war. Next, we identify the critical stakeholders to which those tools will be applied.

Below, we present the biases used in the research. Biases were chosen for their capacity to affect decision-making processes and motivational levels. A thorough examination of behavioral biases was performed to identify those with substantial empirical backing and relevance to wartime scenarios. The biases outlined below will serve as a framework for proposing targeted remedies for the analyzed issue.

Table 1. Review of Research on Behavioral Finance Biases

Bias	**Description**	**Reference**
Sunk Cost Fallacy	The sunk cost fallacy is an emotional error in which investors invest in an unsuccessful investment project, even though it would be a more reasonable choice to withdraw from the investment at a loss. In a military context, it manifests as the tendency to continue committing resources (such as human lives, military equipment, and financial aid) to a prolonged conflict solely due to prior sacrifices.	Arkes and Blumer 1985
Loss Aversion	Loss aversion is a cognitive bias where individuals experience the pain of losses more acutely than the pleasure of equivalent gains, often leading to irrational, risk-seeking behavior to recover those losses. In a war context, nations may risk catastrophic casualties to avoid the pain of territorial loss, rather than accepting a negotiated peace.	Kahneman and Tversky 1979
Framing Effect	The framing effect occurs when people make different decisions depending on how a question is asked. During a conflict, public support often shifts depending on whether	Tversky and Kahneman 1981

	the costs of war are presented as devastating losses or as essential investments in national survival.	
Status Quo	Status quo bias is a behavioral finance bias that explains why people retain their status as it is rather than change it, even if some other alternative is better. In a wartime setting, populations may prefer to endure the severe hardships of an ongoing conflict to preserve their familiar way of life, rather than risk the unpredictable consequences of enemy occupation.	Samuelson and Zeckhauser 1988
Endowment Effect	The endowment effect refers to the tendency of individuals to place a higher value on things they own simply because they own them. In warfare, this means citizens will fiercely defend their own territory and refuse to surrender it for peace, valuing their land far beyond its objective worth.	Thaler 1980
Herd Behavior	Herding behavior is a behavioral bias that states that individuals often behave like other people in their environment. During a conflict, citizens often support the war effort or donate to the military simply because they see others doing it, fearing social rejection if they do not participate.	Banerjee 1992
Inequity aversion	Inequity aversion is a behavioral bias indicating that individuals favor equality over inequality, even when accepting uneven treatment could yield personal benefits. In wartime, this bias can severely damage troop morale if frontline soldiers see draft dodgers safely avoiding service and enjoying social benefits abroad.	Bohmann and Kalleitner 2023
Mental Accounting	Mental accounting is the tendency of people to treat money differently depending on its origin or purpose based on subjective criteria. In military alliances, governments may mentally categorize foreign military aid as fulfilling their own mandatory defense spending targets.	Thaler 1985

Source: Own analysis

The identified biases will be used in the study to analyze the motivations of individuals and propose solutions that can reduce war fatigue and increase motivation to defend the country. It is worth noting that stakeholders may have different motivations and factors that weaken them. For this reason, it was decided to divide the study population into three groups: Ukrainian military personnel, the general Ukrainian society, and allied countries (NATO countries). Such a division will allow for a more detailed analysis and selection of appropriate behavioral finance tools for war fatigue prevention.

The first group is Ukrainian military personnel. This group consists mainly of people actively participating in battles and personnel directly supporting this fight. A high level of stress and constant existential threats characterize this group. For this reason, emotional errors that this group experiences may be significant, while logical errors may be relatively less important. The study aims to identify specific biases to formulate solutions that can improve soldiers' motivation.

The second group includes Ukrainian civilians. This is a much larger and more diverse group than the previous one. This group has significantly different motivations than the previous group. On the one hand, it may be the survival instinct and the need to save the family, and on the other hand, uncertainty about whether one will be drafted into the army. Additionally, this group may be influenced by different individuals who have fled the country and do not participate in the costs of the conflict, which may arouse a sense of injustice.

The third group consists of foreign countries (both society and decision-makers). This group has completely different characteristics than the two previous groups. Members of this group are not directly affected by the conflict, but they indirectly feel its effects. In this group, on the one hand, there may be a strong fear of war and, on the other hand, dissatisfaction with the growing costs of war. These fears are not groundless because a further escalation of the conflict, including the risk of a global or nuclear war, would be a low-probability event with catastrophic consequences and measuring such rare and unprecedented risks remains a serious challenge [Wyluda 2024; Wyluda 2025]. As the conflict develops, the fear of conflict may subside, and cool calculation may come into play, especially if countries have begun to arm themselves and are better prepared and see that Russia has lost significant military resources and will not be able to rebuild them quickly. Over time, there may be a perception that aid to Ukraine is associated with spending money that could be spent on solving domestic problems. Opponents may exploit this situation, which can significantly reduce the government's motivation to continue supporting Ukraine.

3. Results

This section examines how various behavioral finance solutions can increase motivation to defend Ukraine from the enemy. The research aims to identify various types of behavioral biases and the possibilities of their practical application. By dividing the studied population into groups, it is possible to analyze more thoroughly and select appropriate tools.

This section is divided into three parts. Each part examines a different group. First, the focus is on military personnel, then on Ukrainian civilians, and the analysis ends with allies. Behavioral biases that can be applied to each of these groups are selected. Then, a proposal is given for actions that use a given behavioral bias that can increase

motivation to continue the war against the enemy. For each detected bias, precise techniques have been developed to effectively motivate a group.

The analysis starts with the military personnel. For this group, four biases were selected. The proposed applications are presented in Table 2.

Table 2. Application of Behavioral Finance Biases to Motivate Soldiers in Ukraine

Behavioral Finance Bias	**How to Apply in the Context of Ukraine**
Sunk Cost Fallacy	The sunk cost fallacy can be applied to increase the motivation of soldiers. For instance, establishing a compensation scheme in which part of the salary is in Ukrainian war bonds can foster the willingness to continue the war efforts until the strategic objectives are achieved. These bonds can include options to be repaid if Ukraine wins (or achieves certain objectives). This technique can increase soldiers' commitment by linking their financial well-being to the war's outcome. Currently, without these bonds, soldiers may be demotivated and want to end the conflict as quickly as possible at all costs, even if it means defeat for Ukraine. War bonds, in which payment is contingent on victory, can counteract defeatism. Soldiers who have previously devoted time, effort, and financial resources to combat may feel an increased compulsion to continue fighting in order to rationalize these accumulated obligations.
Endowment Effect	The endowment effect can also be used to increase the motivation and commitment of soldiers. There is currently a discussion in Ukraine about giving some land to Russia in exchange for peace. Many soldiers believe that the Ukrainian government should agree to this. This should be more visible to soldiers from the western part of the country, who are not as attached to the eastern part of Ukraine. To solve this problem, the endowment effect can be used by giving land to military personnel in the areas being fought over. In theory, this should reinforce the message of the Ukrainian government, which is trying to stress the historical importance of these lands in Ukraine's heritage. The endowment effect should make this land more valuable to soldiers than its market value. Interestingly, this concept is not new; Aristotle [2004] similarly suggested giving land to border soldiers to increase their motivation to defend the country.
Illusion of Control	The illusion of control can also be used to increase the motivation of soldiers. To mitigate the demotivating effects of forced conscription, a transparent auction recruitment system could be introduced where each conscript bids two amounts. First, how much are they willing to pay to not participate in the conflict, and for what salary are they willing to join the army? The proceeds from these exemptions would fund the war effort, and soldiers could also buy their discharge, giving them a sense of agency without undermining the system.

Inequity Aversion	Inequity bias is a bias that indicates that people are averse to unjust treatment. Thus, even small injustices can demotivate soldiers. For instance, military personnel may experience psychological distress when they hear about the huge social benefits that draft dodgers receive in EU countries. The draft dodgers may be better off financially than soldiers who risk their lives on the front. The system may not only harm soldiers' morale but also incentivize escaping the army. In this case, we should eliminate the factors that trigger inequity bias through policy modification that reduces or eliminates financial and social benefits. According to Notes from Poland [2024], the Ukrainian government already sees the problem and proposes adequate changes.

Source: Own analysis

The second group is Ukrainian society. Since this group is larger and more diverse, a wider set of biases can be used (Table 3).

Table 3. Application of Behavioral Finance Biases to Motivate Ukrainian Society

Behavioral Finance Bias	**How to Apply in the Context of Ukraine**
Loss Aversion	Loss aversion can be employed to increase public support for a military campaign. For instance, the government can point out that society has already made sacrifices and more is needed to win, stressing that Russia will pay for all costs afterward. Giving up the fight means all financial and human sacrifices result in nothing, which triggers loss aversion and increases the willingness to continue the war.
Status Quo Bias	Status quo bias is a cognitive inclination to prefer the present suboptimal state over something uncertain in the future. In other words, individuals favor preserving existing conditions over transformation. This bias can be used in the context of war. For example, society can be motivated to continue the war efforts to continue their lifestyle. This is even though Ukraine did not offer its citizens a high quality of life before the war. The bias can be used to ask citizens of Ukraine for sacrifices in order to avoid life in the Russian Federation.
Herd Behavior	Herd behavior can be employed in the context of war. By promoting group activities in workplaces and schools, the Ukrainian government can trigger herd behavior bias. For instance, a charitable campaign for the Ukrainian army can be launched in an office. If, at the beginning of the campaign, a lot of workers participate, it can pressure others to follow and make donations. The herd behavior bias can make people follow and emulate the behavior of others. Those individuals who do not conform and do not participate in an effort may feel mental discomfort. In some cases, the individual who does not participate may be ostracized.

Framing Effect	Framing Effect can be a helpful tool in the context of war. It is already widely used by propaganda machines. There may be different variations of this effect, and different tools can be used to achieve the results we want. From the behavioral finance point of view, the framing effect can be employed to present financial information differently. For example, the cost of the war can be sold to the public as an investment in the future. The government can stress that the investments in war efforts will benefit future generations.
Endowment Effect	The endowment effect can be employed to impact civilians in Ukrainian society. The government rhetoric should focus on the value of the lost territories to Ukrainian society. If possible, some statistics about valuable resources (minerals) can be presented to influence public opinion. The significance of Ukrainian heritage and historical connection to Ukraine should be strengthened. The sense of ownership can trigger the endowment effect. This, in turn, can reinforce the willingness to protect the contested areas.
Illusion of control	Similarly to the idea presented in the military personnel group, the illusion of control effect can be induced via an auction system of recruiting soldiers. The system will leave people with a possible choice: pay for not being conscripted or go to war. Both of those options are unappealing but can eliminate some mental discomfort. Those drafted may feel they chose to participate in the conflict - not forced to join the army. On the other hand, those who pay for an exemption will not feel stressed or uncertain about whether they will be drafted. The auction approach can provide a legal way to avoid military service and limit corruption. Moreover, it can allow those who escaped conscription to return to Ukraine legally, join the civil labor force, and pay taxes.

Source: Own analysis

The last group consists of the allies of Ukraine. In this case, the motivations are mainly financial and political. The proposed actions are presented in Table 4.

Table 4. Application of Behavioral Finance Biases to Motivate Allies

Behavioral Finance Bias	**How to Apply in the Context of Ukraine**
Sunk Cost Fallacy	Western countries can employ the sunk cost fallacy to sustain support for Ukraine. This strategy can be implemented via war bonds, which can be sold to allied countries or even to individual investors in allied countries. By investing money in the conflict, allies are more willing to support the war efforts. Another way the concept of the sunk cost fallacy can be used is through frozen Russian funds. If Ukraine can finish the war on good terms, it can negotiate compensation from the

	frozen Russian funds. This will help cover the expenses that Western allies have provided for Ukraine.
Mental Accounting	Mental accounting bias can be used to motivate NATO member countries. For instance, every military alliance member must spend 2% of its GDP on defense. Many countries do not spend the agreed 2% and are trying to catch up. Ukraine is trying to convince member countries to treat the money spent on military aid provided to Ukraine as counting toward the 2% goal.
Herd Behavior/Social Proof	The herd behavior can be used to suppress opponents of Ukraine. By showing widespread encouragement for Ukraine, those who do not participate may become alienated. The key element is to gather support from the mass media and leading countries. Securing the backing of the key player country can show that helping Ukraine is the right thing to do. Gathering public support from the media can pressure hesitant countries and individuals. Moreover, countries and individuals unwilling to help Ukraine run the risk of social exclusion. The reluctance and objection to the support may result in ostracism and social marginalization in certain instances.

Source: Own analysis

4. Discussion and ethical considerations

The recommended strategies involve using logical and psychological biases used in behavioral finance. However, the strategies should be analyzed from an ethical perspective. The use of behavioral finance in support of the war effort is a complex problem.

First of all, the key thing is to distinguish between legitimate persuasion and illegitimate manipulation. Persuasion respects the autonomy of individuals by providing information and framing choices in a way that encourages the making of decisions based on individual values. Manipulation involves lying or taking advantage of cognitive frailties, regardless of the welfare or interest of the individuals concerned [Sunstein 2016]. In the application of these techniques, it is important that the information provided is true and that the persons are not being pushed to do things that are not in their interest. Any framing effects should highlight the valid positive attributes of the military effort and not deceive the citizens about associated risks or consequences. Respecting individual autonomy means allowing persons to make decisions based on full information.

Second, even if behavioral finance is not used to support the war effort due to ethical concerns, the analysis is still needed because the adversary may not share our ethical values. At the very least, we should understand the techniques that are used by adversaries. Optimally, preemptive measures should be taken to tackle the psychological tools applied by enemies. For most of the biases, understanding the

mechanism of the bias and educating society or informing the public about it can be sufficient. Thus, monitoring and educating the public and informing the mass media are essential.

Third, some of the biases, when employed, can have some unforeseen adverse consequences for the mental health of individuals. For instance, excessive framing of messages in terms of loss aversion and identification of potential threats may create unjustified fear or anxiety among the population. Therefore, the messages should be balanced to keep people aware but not overly anxious. The consequences of implementation of such tools can last for many years and even generations because trauma can be transferred from generation to generation.

Fourth, excessive use of psychology in military engagement may cause long-term distrust of the government. If possible, decision-makers must be transparent in their strategies and accountable for their actions. Public trust is paramount, and any appearance of manipulation or wrongdoing can undermine support and heighten war fatigue [Rawlins 2008].

Lastly, the analysis should be done on a case-by-case basis before the implementation of behavioral finance tools. For instance, policies aiming at the removal of social benefits to draft dodgers should be applied individually. The implementation of such a tool to all citizens of a given country can not only be unethical and unjust but also cause public backlash. Thus, policies should not affect the most vulnerable sections of our society.

Overall, behavioral finance tools can be used as weapons. Like any weapon, they can be used to defend or to attack. The ethicality of such tools should be analyzed and studied. The decision-makers in NATO countries cannot count on enemies not using them or not developing the best strategies to influence societies.

Conclusion

The ongoing war in Ukraine brings important challenges. One such challenge is war fatigue. In this paper, we analyzed the possibility of the use of new advancements in behavioral finance to combat war fatigue. In order to do so, we divided the population into three distinct groups: military personnel, civilians in Ukraine, and allied countries. After the division, each bias was analyzed from the perspective of practical implementation.

In the first group, military personnel, we identified four biases that can be applied. [1] The sunk cost fallacy can be used in compensation packages for soldiers. The analysis suggests the possibility of using war bonds linked to the success of Ukraine, which incentivizes the continued war effort to ensure that past sacrifices do not look like a waste. [2] The endowment effect could be tapped by giving soldiers land near borders. [3] The illusion of control would help alleviate the demotivating aspect of

forced conscription through the use of an auction system that allows soldiers to bid on exemptions or modifications in terms of service, providing a sense of choice. [4] Finally, inequity aversion suggests that soldiers may be demotivated by draft dodgers who receive generous benefits in European Union countries. Thus, eliminating such social benefits would help boost soldiers' morale.

The behavioral finance concepts can be widely used in the second group, which is comprised of civilians in Ukraine. [1] The loss aversion bias can be utilized by emphasizing what the society has already invested in the war, and that giving up would not be wise. Moreover, suggestions that after winning, Russia will pay for all destruction can be encouraging. [2] The status quo bias can be employed in urging civilians to support the war efforts by suggesting uncertainty under Russian occupation. [3] The Ukrainian government can trigger herd behavior bias by promoting group activities in workplaces and schools, which, in turn, can suppress opposition to the war via social pressure. [4] The framing effect can be applied by presenting the costs of war as an investment in the future of Ukraine, emphasizing possible long-run gains for future generations. [5] The endowment bias can be utilized, stressing the importance of heritage and historical ownership. [6] Lastly, an auction system can induce the illusion of control bias. The system will leave people with a choice: pay for not being conscripted or go to war. Both options are unattractive, but giving the choice eliminates some mental discomfort.

Lastly, the behavioral finance concepts were applied to the allies. [1] The sunk cost fallacy will further ensure that the allies remain constantly supportive. Their financial input in war bonds and loans is directly attached to Ukraine's victory and the potential recovery of the frozen Russian assets. [2] Mental accounting can persuade the NATO countries to count military aid to Ukraine toward their required 2% defense spending targets. [3] Using the herd behavior concept, decision-makers can influence reluctant countries and individuals to support Ukraine's war effort.

In the last part of the paper, we analyze the ethicality of implementing behavioral finance tools in the context of war. We stressed the importance of [1] differentiation between persuasion and manipulation, [2] studying and monitoring the concepts to understand the actions of opponents, [3] analyzing adverse consequences on the mental health of individuals, [4] excessive use of psychological tools in the context of distrust for the government, [5] applying the tools on a case-by-case basis in order to avoid harming the most vulnerable.

This research explores the possibility of using behavioral finance concepts in the war area. It outlines how policymakers can effectively address war fatigue. Further research, especially empirical analysis, is needed to determine the effectiveness of the tools.

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