ISSN: 1683-1942
E-ISSN: 2304-6155
УДК: 33

Харківський національний економічний університет імені Семена Кузнеця

ЕКОНОМІКА РОЗВИТКУ

Міжнародний економічний журнал

Заснований у 2002 році
Періодичність випуску: 4 рази на рік

Том 25, № 3

Харків – 2026

ISSN: 1683-1942
E-ISSN: 2304-6155
UDC: 33

Simon Kuznets Kharkiv National University of Economics

ECONOMICS OF DEVELOPMENT

International Economic Journal

Founded in 2002
Frequency of issue: Four times per year

Volume 25, No. 3

Kharkiv – 2026

ISSN:1683-1942
E-ISSN: 2304-6155
УДК: 33

Засновник та видавець:
Харківський національний економічний університет імені Семена Кузнеця

Рік заснування: 2002

Рекомендовано до друку та поширення
через мережу Інтернет Вченою радою
Харківського національного економічного університету імені Семена Кузнеця
(протокол № 11 від 01 вересня 2026 р.)

Ідентифікатор медіа: R30-02690
(Рішення Національної ради України
з питань телебачення і радіомовлення
№ 177, протокол № 3 від 25 січня 2024 р.)

Журнал входить до переліку наукових фахових видань України
Категорія «Б». Спеціальності: С1 Економіка; С3 Міжнародні відносини; D1 Облік і оподаткування; D2 Фінанси, банківська справа, страхування та фондовий ринок; D5 Маркетинг; D7 Торгівля
(Наказ Міністерства освіти і науки України № 928 від 11.06.2026)

Кластер: Економічні перетворення, бізнес та адміністрування

Журнал представлено у міжнародних наукометричних базах даних, репозитаріях та пошукових системах:
Фахові видання України, Національна бібліотека України імені В. І. Вернадського, Crossref, Polska Bibliografia Naukowa, Universitäts Bibliothek Leipzig, BASE, Litmaps, EconBiz, WorldCat, Ulrichsweb Global Serials Directory, UCSB Library, Dimensions, German Union Catalogue of Serials (ZDB), ERIH PLUS, University of Oslo Library, University of Hull Library, Search Oxford Libraries Online (SOLO), European University Institute (EUI), Cambridge University Library, Open Ukrainian Citation Index (OUCI), IDEAS/RePEc

Економіка розвитку : міжнар. екон. журн. / [редкол.: Т. В. Шталь (голов. ред.) та ін.]. – Харків : Харківський національний економічний університет імені Семена Кузнеця, 2026. – Т. 25, № 3. – 83 с.

Адреса редакції:
Харківський національний економічний університет імені Семена Кузнеця
61166, пров. Інженерний, 1-А, м. Харків, Україна
Тел. +380 (57) 702-03-04
E-mail: info@ecdev.com.ua
https://ecdev.com.ua/uk

ISSN: 1683-1942
E-ISSN: 2304-6155
UDC: 33

Founder and publisher:
Simon Kuznets Kharkiv National University of Economics

Year of foundation: 2002

Recommended for printing and distribution
via the Internet by the Academic Council
of Simon Kuznets Kharkiv National University of Economics
(Minutes No. 11 September 01, 2026)

Media identifier: R30-02690
(Decision of the National Council
of Television and Radio Broadcasting of Ukraine
No. 177, Minutes No. 3 of January 25, 2024)

The journal is included in the List of Scientific Professional Publications of Ukraine
Category "B". Specialties: 0311 Economics; 0312 Political sciences and civics; 0411 Accounting and taxation; 0412 Finance, banking and insurance; 0414 Marketing and advertising; 0416 Wholesale and retail sales
(Order of the Ministry of Education and Science of Ukraine No. 928 of 11.06.2026)

Cluster: Economic transformation, business and administration

The journal is presented in the international scientometric databases, repositories and scientific systems:
Professional publications of Ukraine, Vernadsky National Library of Ukraine, Crossref, Polska Bibliografia Naukowa, Universitäts Bibliothek Leipzig, BASE, Litmaps, EconBiz, WorldCat, Ulrichsweb Global Serials Directory, UCSB Library, Dimensions, German Union Catalogue of Serials (ZDB), ERIH PLUS, University of Oslo Library, University of Hull Library, Search Oxford Libraries Online (SOLO), European University Institute (EUI), Cambridge University Library, Open Ukrainian Citation Index (OUCI), IDEAS/RePEc

Economics of Development / Ed. by T. Shtal (Editor-in-Chief) et al. Kharkiv: Simon Kuznets Kharkiv National University of Economics, 2026. Vol. 25, No. 3. 83 p.

Editors office address:
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Том 25, № 3

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ECONOMICS OF DEVELOPMENT Volume 25, No. 3

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ECONOMICS OF DEVELOPMENT
Journal homepage: https://ecdev.com.ua/
ISSN: 1683-1942
E-ISSN: 2304-6155
Vol. 25, No. 3, 2026
UDC 338.1:004
DOI: 10.63341/econ/3.2026.08

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Digital-transformation analytics for developing-economy small enterprises: A complement-internalisation framework

Abstract. Analytics-led digital transformation has become a central instrument of small-enterprise growth, yet the frameworks that describe it were derived almost entirely from firms operating in advanced economies, where the environment supplies most of the assets that analytics requires. Recent statistical evidence has shown that connectivity and digital payment spread rapidly across developing economies over the past decade, while data systems, analytical skills and reliable last-mile infrastructure did not, which has left small enterprises exposed to transformation prescriptions their institutional environment cannot support. The purpose of the study was to develop a conceptual framework that explained analytics-led transformation in developing-economy small enterprises as the sequenced internalisation of the complementary assets that the surrounding institutional environment failed to supply. The study was designed as a theory-development critical review. A theoretical core was assembled from foundational works on complementary assets, absorptive capacity, dynamic capabilities and institutional voids, and a recent-evidence base was assembled through structured searches of scholarly databases across the publication years 2020-2026, restricted principally to peer-reviewed venues and to flagship international statistical reports. Four analytical stages produced the framework: constraint mapping, complement-class derivation, principle formulation and pathway specification. The analysis established four classes of missing complement, namely informational, human-capital, organisational and infrastructural, and specified an internalisation mechanism appropriate to each: self-instrumentation, absorptive-capacity bootstrapping, minimal co-invention and leapfrogging. The synthesis yielded the binding-complement principle, according to which the scarcest complement rather than technological ambition set the pace and the shape of transformation, and a cyclic pathway along which the binding complement migrated as each complement was relieved. The framework offers managers a diagnostic order of operations and policymakers a firm-level vocabulary for targeting ecosystem interventions. All illustration was hypothetical and no empirical data were reported

Keywords: absorptive capacity; dynamic capabilities; self-instrumentation; technology leapfrogging; institutional voids; complementary assets; technology diffusion

INTRODUCTION

The digital environment in which developing-economy small enterprises operate changed materially over the decade preceding this study, but it changed unevenly, and the pattern of that unevenness is what makes the present question urgent. Financial-inclusion measurement by L. Klapper *et al*. (2025), covering the period to 2024, recorded a broad diffusion of mobile-phone ownership and of digital payment across low- and middle-income countries, so that the transactional surface on which analytics could in principle operate became far wider than it had been. Yet the same period produced no comparable convergence in the underlying capacity to use data. The World Bank (2024) documented that cloud services, data-processing capacity and advanced analytical tools remained concentrated in high-income economies, and that an emerging divide in artificial-intelligence

Article's History: Received: 15.04.2026; Revised: 23.07.2026; Accepted: 01.09.2026; Published: 02.10.2026

Suggested Citation:
Bozieva, L. (2026). Digital-transformation analytics for developing-economy small enterprises: A complement-internalisation framework. *Economics of Development*, 25(3), 8-21. doi: 10.63341/econ/3.2026.08.

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capability threatened to reproduce, at a higher technological level, the divide that connectivity had begun to close. The OECD (2021), in its policy analysis of small and medium-sized enterprises, reached the same conclusion from the firm side, finding that digital adoption among smaller firms lagged persistently behind that of large firms and that the gap was widest for data-intensive applications rather than for basic connectivity. The relevance of the present study follows directly from this configuration: access has advanced, capability has not, and the frameworks that firms are advised to follow were written for an environment in which capability could be assumed.

That advice originates in a body of scholarship that has grown rapidly and that deserves analytical rather than ceremonial treatment. G. Vial (2019) characterised digital transformation as a process of strategic renewal in which digital technologies reconfigure value creation, operations and organisational structure rather than as an act of technology acquisition. That account established the primacy of organisational change convincingly, yet it left the supply of the non-organisational inputs unexamined, because in the settings it synthesised those inputs were purchasable. Case evidence on smaller firms sharpened the same insight without closing the same gap. M. Matarazzo *et al*. (2021), in a study of Italian small and medium-sized manufacturers, established that digital transformation created customer value only where firms possessed the dynamic capabilities to reconfigure around the technology, and J. Soluk & N. Kammerlander (2021), in a multiple-case study of family-owned Mittelstand firms, established that transformation proceeded through distinguishable stages of process, product and business-model digitalisation, each requiring its own dynamic capabilities. What none of these studies could address is whether the capability-building sequence they describe survives translation into an environment where the external data, the skilled labour and the reliable infrastructure that their firms took for granted are themselves scarce.

Studies conducted in developing and emerging economies confirmed the scarcity but stopped short of a firm-level theory of what to do about it. A.A.F. Alalawneh & S.F. Alkhatib (2021), in an examination of barriers to big-data adoption in developing economies, established that the leading obstacles were infrastructural, informational and skills-related rather than attitudinal, and M.M.H. Shahadat *et al*. (2023), in a large-sample study of small and medium-sized enterprises in an emerging country, established that adoption was driven by perceived cost, top-management support and government support, with organisational readiness exerting no significant effect. J. Díaz-Arancibia *et al*. (2024), in a systematic review of transformation and technology adoption among small firms in developing countries, established that adoption in these settings remained concentrated in basic information systems, with cloud computing and artificial intelligence comparatively rare, and identified community-driven and ecosystem factors as the principal facilitators. Each of these results diagnoses a deficit. None specifies the order in which a single firm should remedy the deficits it faces, and the reviews explicitly call for adoption models tailored to the constraints of developing-country enterprises rather than imported from elsewhere.

A parallel line of enquiry on analytical capability has established what such capability yields once it exists, which is precisely the part of the problem that developing-economy firms have not yet reached. L. Ardito *et al*. (2025), using firm-level evidence from a large sample of European small and medium-sized enterprises, established that the adoption of artificial intelligence was associated with higher revenue growth, and that the association was stronger where the technology was combined with the internet of things and big-data analytics, which the authors interpreted through the literature on digital complementary assets. T. Justy *et al*. (2023), in research on adoption barriers in smaller firms, established that the impediments were managerial, human and informational before they were technological. Taken together, these studies establish that analytical capability pays only in combination with other assets, and they thereby raise, without answering, the question that arises when several of those other assets are institutionally absent rather than merely underdeveloped.

The gap that the present study addressed lies at the junction of these two bodies of work. The transformation and analytics-capability literature explain why technology produces value only in combination with organisational and human complements, but it studies firms embedded in environments that supply most non-organisational complements through the market. The development literature explains why those environments are precisely what developing economies lack, but it studies the phenomenon chiefly at the level of countries, sectors and aggregate diffusion. Neither asks what analytics-led transformation becomes when the complements that one tradition treats as external and given are the very assets the other shows to be missing. The stakes of that question are not confined to the firm. D. Comin & M. Mestieri (2018), using cross-country evidence, established that modern income divergence was driven less by lags in the timing of technology adoption than by persistent gaps in the intensity of use once adoption occurred, and X. Cirera & W.F. Maloney (2017), in their analysis of the innovation paradox, established that firms in developing countries under-invest in technology despite high measured returns because the complementary capabilities needed to capture those returns are absent. Analytics-led transformation at the small-enterprise level is exactly a mechanism of intensive-margin technology use, which makes a firm-level account of complement supply a microfoundation for a macroeconomic puzzle.

The purpose of this study was to develop a conceptual framework that explained analytics-led digital transformation in developing-economy small enterprises as the sequenced internalisation of the complementary assets that the surrounding institutional environment failed to supply. Three tasks were set in order to achieve that purpose. The first task was to map the institutional constraint environment of the developing-economy small enterprise onto the classes of complementary asset that analytics-led transformation requires, distinguishing the gaps that had narrowed from those that persisted. The second task was to specify, for each class, the mechanism by which the firm could supply the complement internally, and to formulate the principle that governed the order in which the mechanisms were applied. The third task was to derive the transformation pathway implied by that principle and to demonstrate its

operation through an explicitly hypothetical illustration. The scientific novelty of the study consisted in the formulation of the binding-complement principle, which established that the scarcest complementary asset rather than technological ambition determined the pace and the shape of analytics-led transformation, and in the integration of the complementary-assets and institutional-voids traditions into a single firm-level pathway that had not previously been specified.

MATERIALS AND METHODS

The study was designed as a theory-development critical review rather than as an empirical investigation, and it reported no primary data. This design was selected because the objective was the construction of a framework capable of organising established results into a coherent account of a phenomenon that had not been theorised at the firm level, rather than the testing of hypotheses derived from an existing account. The theoretical core of the framework was assembled from foundational works in four traditions selected for their direct bearing on the research purpose: the economics of complementary assets and of information technology, which supplies the proposition that technology yields value only in combination with organisational and human assets; the absorptive-capacity tradition, which supplies the account of how firms assimilate knowledge they did not generate; the dynamic-capabilities tradition, which supplies the conception of transformation as ongoing capability renewal; and the development economics of institutional voids and technology diffusion, which supplies the description of the environment in which the developing-economy firm operates. These works were selected on the criterion of foundational status within their tradition, established by citation weight and by their standing as the canonical statement of the construct in question.

The recent-evidence base was assembled through structured searches of scholarly databases, conducted with the Semantic Scholar corpus and with all bibliographic metadata subsequently verified against the Crossref registry, over the publication years 2020-2026. Six search-term families were used: small-enterprise digital transformation in developing and emerging economies; big-data analytics capability and firm performance; absorptive capacity and dynamic capabilities in digitalisation; institutional voids and digital platforms; mobile money, financial technology and financial inclusion; and digital infrastructure, the digital divide and technological leapfrogging. Fifteen topic-specific sweeps across these families returned approximately three hundred records. Inclusion criteria were as follows: publication in a peer-reviewed scholarly journal, with preference given to venues indexed in Scopus or the Web of Science; publication within the stated window; thematic relevance to at least one of the four complement classes or to the current state of digital infrastructure in developing economies; and, for statistical evidence on the environment itself, publication as a flagship statistical or policy report of the World Bank or the Organisation for Economic Co-operation and Development. Excluded were non-peer-reviewed venues, conference abstracts, records without verifiable bibliographic metadata, and studies whose results proved thematically peripheral on inspection of the abstract. Working papers from established economic research programmes were admitted sparingly, and only where no equivalent peer-reviewed result was available. After de-duplication and screening, thirty-six recent studies and reports were retained and merged with a foundational core of eighteen works, yielding the evidence base of fifty-four sources on which the analysis was conducted, thirty-two of them published between 2021 and 2026.

The framework itself was produced through four analytical stages applied in sequence. In the first stage, constraint mapping, the structural features of the developing-economy operating environment reported in the development literature and in current statistical evidence were extracted and restated in the vocabulary of complementary assets, so that each documented constraint was expressed as an asset the environment failed to supply. In the second stage, complement-class derivation, the restated constraints were grouped by the type of asset withheld, and the grouping was tested for exhaustiveness against the requirements of an analytical decision cycle, which yielded four classes. In the third stage, principle formulation, the complementarity result from the economics of information technology was applied to the derived classes in order to establish the rule governing the order of internalisation. In the fourth stage, pathway specification, the principle was translated into a sequence of firm-level actions, each defined by its input, its action and its expected conceptual output, and the sequence was closed into a cycle by the observation that relieving one complement raises the marginal value of the others. The claim advanced by this procedure was not that any single constraint is unique to developing economies, but that the conjunction of the constraints, and their institutional rather than merely quantitative character, changes what transformation requires. The features derived below were stated throughout at the level of the individual small enterprise. The source groups on which the analysis drew, and the specific contribution each made to the study, are set out in Table 1.

Table 1. Source groups used in the analytical synthesis

Source group	Representative sources	Information obtained for the study
Digital transformation and dynamic capabilities	G. Vial (2019), K.S.R. Warner & M. Wäger (2019), J. Soluk & N. Kammerlander (2021)	Conception of transformation as strategic renewal and capability building rather than technology acquisition; staged structure of the transformation process; the organisational locus of change
Economics of information technology, complementarity and analytics capability	D.J. Teece (1986), E. Brynjolfsson & L.M. Hitt (2000), T.H. Davenport & J.G. Harris (2007), H. Chen *et al*. (2012)	The complementary-assets proposition; evidence that computing raises performance only alongside organisational redesign and skills; the definition of analytics as an embedded decision capability
Development economics and institutional voids	C.K. Prahalad (2005), T. Khanna & K.G. Palepu (2010), X. Cirera & W.F. Maloney (2017)	Characterisation of missing market intermediaries; the innovation paradox and missing complementary capabilities; value creation under binding resource constraints

Table 1. Continued

Source group	Representative sources	Information obtained for the study
Current statistical and policy reports	World Bank (2021), A. Demirgüç-Kunt *et al.* (2022), F. Ohnsorge & S. Yu (2022)	Current state of data systems, data infrastructure and data intermediaries; diffusion of digital payment instruments and financial inclusion; the scale and persistence of informality
Recent developing-economy small-enterprise evidence	T. Justy *et al.* (2023), J. Díaz-Arancibia *et al.* (2024), S.S. Ky & C. Rugemintwari (2025)	Ranking of adoption barriers; the prevalence of basic rather than advanced digital tools; firm-level uptake of digital payment instruments in the informal sector

Source: compiled by the author

One limitation of the design was addressed explicitly in the construction of the manuscript. Because no empirical study was conducted, the single extended illustration presented in the Results is hypothetical in its entirety. It refers to no real firm and no real dataset, it reports no numeric results, and it was constructed solely to demonstrate the composition of the principle and the pathway. Any resemblance to a specific enterprise is unintended.

RESULTS

The constraint environment mapped onto four missing complements

The first stage of the analysis restated the documented features of the developing-economy operating environment as classes of complementary asset that the environment fails to supply. A precondition of that restatement was an accurate account of which features had changed. The analysis established that the institutional-voids description, formulated before the diffusion of mobile connectivity and digital payment, remains valid in its structure but requires substantial revision in its particulars, because two of the four complements have been materially relieved from outside the firm while two have not.

The gaps that narrowed were those associated with transaction and connection. Financial-inclusion measurement through 2024 recorded that mobile-phone ownership and the use of digital payment instruments expanded substantially across low- and middle-income economies, extending both the reach of formal financial services and the volume of transactions leaving a digital trace (Klapper *et al.*, 2025); the earlier round of the same measurement programme had already recorded the beginning of that expansion under the conditions of the pandemic (Demirgüç-Kunt *et al.*, 2022). Research on ride-hailing platforms in developing countries established the mechanism behind part of this change: platform firms entering markets characterised by institutional voids performed internally, and at scale, market functions that had previously been distributed or absent, producing markets that were more complete and more formalised even as the platforms created new voids of their own (Heeks *et al.*, 2021). A large cross-country study established the same substitution in the financial domain, showing that mobile-money platforms filled institutional voids by enabling data-based certification, by providing unified access to distributed services and by scaling through network effects to reach previously excluded participants, thereby extending credit access from formal institutions (Agarwal & Assenova, 2024). Firm-level evidence from Burkina Faso established that this reach extended into the informal sector itself, with unregistered businesses adopting and using merchant mobile-money accounts under conditions of considerable uncertainty (Ky & Rugemintwari, 2025). The analysis therefore established that intermediation of payment and of market matching is no longer reliably absent, and that a framework built on the assumption of its absence would misdescribe the current environment.

The gaps that persisted were those associated with data and with capability. Comprehensive assessment of data systems in developing countries established that the institutional apparatus required to convert data into value, comprising statistical capacity, data infrastructure, data-governance rules and the intermediaries that assemble and certify information, remained weak and unevenly distributed, so that the data generated by expanding connectivity were frequently not usable by the firms that generated them (World Bank, 2021). Assessment of digitalisation trends established that cloud services, data-processing capacity and advanced analytical tooling remained concentrated in high-income economies, with an emerging divide in artificial-intelligence capability positioned to widen rather than close (World Bank, 2024). Spatial analysis of the digital divide within Sub-Saharan Africa established that access to internet and broadband continued to be determined by income per capita, capital formation, regulatory efficacy and, notably, electricity infrastructure, with substantial spillovers between neighbouring economies, which indicates that the residual divide is infrastructural and institutional rather than a matter of handset penetration (Myovella *et al.*, 2021). Comparative cross-country analysis established that mobile broadband, rather than internet bandwidth, was the variable through which information and communication technologies advanced human development in developing countries, whereas in developed countries the reverse held, which locates the developing-economy constraint at the level of capacity rather than of connection (Bala, 2024). The analysis accordingly established that the informational and infrastructural environment has become bifurcated: the first, thin layer of digital participation is widely available, and the deeper layer on which analytics depends is not.

Against that updated background, four constraints were mapped onto four missing complements. Absent informational intermediaries. A firm beginning an analytics transformation in an advanced economy inherits a dense supply of external information, including syndicated market research, credit-bureau records, geodemographic databases, industry benchmarks and the transactional residue of formal counterparties. Much of this is a purchasable input. In developing economies, the intermediaries that produce and sell such information are frequently thin or absent, which is the paradigmatic institutional void (Khanna & Palepu, 2010), and the void is compounded by informality, which removes a large share of transactions from

any formal record (Ohnsorge & Yu, 2022). Firm-level survey evidence established that informal competition remained a material feature of the environment faced by formal manufacturing small and medium-sized enterprises in developing and emerging countries, with consequences for their own growth and employment decisions (Amin, 2022), which indicates that the unrecorded segment of the market is not a residual but a structural part of the demand a firm must understand. Where intermediation of business information has begun to emerge, it has done so by substituting soft information for the hard records that do not exist: a multi-case study of Indian banks established that digitalisation was used to verify relationship-based and plan-based information about small enterprises where conventional credit records were unavailable (Hardik, 2023). The analysis established that the missing complement in this class is informational: the firm can neither buy nor borrow the data its analytics require, and a substantial share of the relevant activity is not recorded anywhere.

Thin markets for analytical human capital. Analytics-led transformation requires people who can specify a question, prepare and interrogate data, and translate a result into a decision. Advanced economies supply such people through deep labour markets and a large stock of tacit organisational know-how. Developing economies present thin and geographically concentrated markets for these skills, and the broader managerial capital needed to deploy them well is itself scarce and unevenly distributed (Bloom & Van Reenen, 2010). Because absorptive capacity depends on prior related knowledge (Cohen & Levinthal, 1990), the scarcity is self-reinforcing: a firm holding little existing analytical knowledge finds it correspondingly harder to assimilate more. The analysis established that the missing complement in this class is human-capital: the skills and the absorptive capacity that convert tools into use.

Scarce managerial and organisational capital. Even where data and skills exist, analytics changes nothing unless a decision changes, which requires that a process be redesigned, a decision right reassigned or an incentive realigned so that the output of analysis actually alters behaviour. The complementary-assets literature identified this organisational reconfiguration as the true seat of value, arguing that the largest component of the value created by information technology lies in the organisational transformation it enables rather than in the technology itself, and that the required changes are costly, time-consuming and firm-specific (Brynjolfsson & Hitt, 2000). Firm-level evidence established that information technology, workplace reorganisation and skilled labour operate as mutual complements, so that the return to any one of them rises with the presence of the others (Bresnahan *et al.*, 2002). This is the one complement that must be co-invented within the firm even in advanced economies. In developing economies, the difficulty is compounded, because average managerial practice is less developed and because owner-centric small enterprises frequently lack the delegation structures that data-driven decision-making presupposes. The analysis established that the missing complement in this class is organisational: the redesigned processes and decision rights without which analysis is inert.

Intermittent but leapfroggable infrastructure. Analytics presupposes an infrastructure of connectivity, power, computation and storage. In developing economies this infrastructure is real but uneven, dependable in major urban centres and intermittent beyond them, with electricity provision and regulatory quality among its binding determinants, as the spatial evidence reviewed above established. The constraint is nonetheless double-edged. The same conditions that make legacy on-premise digitisation impractical also open the possibility of leapfrogging directly to mobile-first, cloud-hosted and frugally engineered architectures that skip the stages advanced economies passed through (Steinmueller, 2001). Evidence on the arrival of fast internet in Africa established substantial positive effects on employment (Hjort & Poulsen, 2019), and subsequent evidence on the expansion of third-generation mobile internet across developing countries established increases in labour-force participation and in small-enterprise operation, with distinct effects by gender (Chiplunkar & Goldberg, 2022). The analysis established that the missing complement in this class is infrastructural, but that, unlike the other three, it can often be supplied by adoption rather than by construction, provided the firm resists the temptation to replicate the advanced-economy technology stack.

The synthesis yielded a common structure across the four features. Each corresponds to a complement that analytics-led transformation requires and that the advanced-economy firm largely obtains from its environment: information, skilled human capital, organisational reconfiguration and infrastructure. In the advanced-economy setting three of the four, all but the organisational, are substantially supplied by the market and by institutions, so that the transformation task reduces mostly to internal organisational change plugged into an otherwise supportive environment. In the developing-economy setting the environment supplies far less, and the firm confronts the prospect of having to supply several complements at once, from within. This shift, from internalising one complement into a rich environment to internalising several into a sparse one, is what the analysis established as the structural distinction of developing-economy transformation, and it is the condition that the framework below was designed to manage.

The four complements as objects of internalisation

The second element of the framework specified each complement as an object the firm must supply internally when the environment does not, together with the internalisation mechanism appropriate to it. The mechanisms below are author-derived outputs of the synthesis; the results cited within them are the literature-supported propositions on which each mechanism rests. The informational complement is internalised through self-instrumentation. When no intermediary sells the data and informality hides much of the market, the firm must manufacture its own information by instrumenting its own operations and points of contact, converting every interaction it does control into a recorded, structured observation. A point of sale becomes a data-collection instrument; a delivery route becomes a source of geographic demand signal; a customer conversation becomes a captured, coded field. Self-instrumentation reconceives data not as an input the firm receives but as an output the firm produces, and the analysis established

it as the firm-level substitute for the absent informational intermediary. The mechanism is consistent with the emergence of soft-information intermediation in thin-record environments established above, with the difference that the framework locates the production of the substitute record inside the transacting firm rather than inside the lender. It also reframes analytics, at least initially, as a means of building the firm's proprietary informational asset rather than of mining a pre-existing one.

The human-capital complement is internalised through absorptive-capacity bootstrapping. Because skilled analysts are scarce and absorptive capacity is low, the firm cannot hire its way to capability in a thin market. It must instead bootstrap: begin with a small, deliberately cultivated nucleus of analytical understanding, leverage external knowledge aggressively through open methods, cloud-hosted tooling, advisory relationships and increasingly capable machine-learning systems that lower the skill threshold for a given analytical task, and expand the internal knowledge base incrementally so that each increment raises the capacity to absorb the next (Cohen & Levinthal, 1990). Evidence from small and medium-sized enterprises established that potential absorptive capacity, comprising the acquisition and assimilation of external knowledge, drove both strategic flexibility and business-model innovation, while realised absorptive capacity raised flexibility directly (Miroshnychenko *et al.*, 2021), which supports the framework's emphasis on the acquisition stage as the point of entry for a resource-constrained firm. Machine-learning tools enter the framework strictly as instruments that reduce the scarcity of the human-capital complement rather than as the subject of transformation; firm-level evidence that the adoption of artificial intelligence was associated with the highest revenue growth where it was combined with analytics and connected devices is consistent with that instrumental reading (Ardito *et al.*, 2025). Their role, in the framework's terms, is to let a small team accomplish what a large one otherwise would.

The organisational complement is internalised through minimal co-invention. Since analysis changes nothing unless a decision changes, the firm must redesign the specific process, decision right or incentive that a given analytical output is meant to influence. Firm-level evidence from eighty-two developing economies established that the productivity premium associated with digital-technology adoption operated jointly with other firm choices, including managerial experience and exporting, and the authors explicitly examined complementarities among those choices (Pena *et al.*, 2020), which locates the same complementarity result in the setting the framework addresses. The discipline the framework imposes is minimality: the firm co-invents the smallest organisational change that lets one decision become data-driven, rather than attempting an enterprise-wide restructuring it lacks the managerial capital to execute. Minimal co-invention respects the scarcity of managerial capital by spending it where a single, observable decision will change, and it builds the delegation and routine that later, larger reconfigurations will require.

The infrastructural complement is internalised through leapfrogging. Rather than constructing the legacy stack that advanced-economy firms accumulated over decades, the developing-economy firm adopts mobile-first, cloud-hosted and frugally engineered infrastructure that matches its constraints and skips the stages it need not repeat (Steinmueller, 2001). The mechanism draws on the established observation that firms in resource-constrained settings create value by engineering around constraints rather than assuming them away (Prahalad, 2005; Zeschky *et al.*, 2011). Of the four complements this is the one most often supplied by adoption rather than by construction, which is why leapfrogging can relieve it comparatively quickly, and why the analysis established that it is frequently not the binding complement once the firm resists over-building.

The governing principle:
The binding complement governs

The synthesis yielded a single governing principle: in a developing-economy small enterprise, the pace and the shape of analytics-led transformation were set not by technological ambition but by the binding complement, which is the scarcest of the complementary assets the transformation requires. This principle inverts the implicit logic of the transplanted playbook, which sequences transformation by technological maturity, acquiring the platform, then the data, then the models, then the use cases. Under the binding-complement principle, the firm sequences transformation by scarcity: it identifies which complement is most limiting at a given moment, concentrates its effort on internalising that complement, and treats technology acquisition as subordinate to, and paced by, complement supply.

The principle follows directly from the complementary-assets result. If information technology, organisational change and skilled labour are mutual complements, so that the return to each rise with the presence of the others (Bresnahan *et al.*, 2002), then investment in any single complement while another remains at zero yields little. The proposition has a deeper root in the analysis of complementary assets, which established that the profits from an innovation flow not to the innovator alone but to whoever controls the specialised assets the innovation requires (Teece, 1986). A firm that buys sophisticated analytical software while holding no usable data, or that accumulates data it has no organisational mechanism to act upon, has not transformed; it has stranded capital in an unbalanced complement bundle. The binding-complement principle is the operational discipline that keeps the bundle balanced, directing effort to the margin at which the complementary system is weakest, because that is the margin at which additional effort raises the productivity of everything else.

Two features distinguish this principle from a maturity ladder and from an investment-prioritisation rule, and both distinctions matter for its application. It is not a maturity ladder, because the binding complement is not a fixed stage through which every firm passes in the same order; it is a firm-specific and moment-specific diagnosis that can differ across enterprises facing the same technology and that migrates within a single firm over time. It is not a rule for ranking capital expenditures by financial return, because the complements it sequences are predominantly capabilities, comprising information the firm manufactures, skills it cultivates and processes it redesigns, most of which are

built through organisational effort rather than purchased, and because the principle is silent on how any infrastructure spend should be financed. What the principle governs is the order in which capabilities are internalised, not the appraisal of an investment.

The framework that follows from the principle describes a process of becoming rather than a state to be measured or a purchase to be justified. Its unit of analysis is the changing configuration of the firm's complementary system as it internalises, in sequence, the assets its environment withholds. Transformation, in this account, is the trajectory along which the binding complement is repeatedly identified and relieved until the complementary system is balanced enough to sustain data-driven operation. This is a deliberately dynamic, capability-building conception, aligned with the view of transformation as the ongoing renewal of higher-order routines through which a firm adapts its ordinary capabilities to change (Teece, 2007).

Accordingly, the principle establishes a practical criterion for advancing the transformation: the firm should proceed to the next technological or organisational step only after the currently binding complement has been relieved sufficiently for another constraint to become dominant. This criterion converts complementarity from an explanatory proposition into a sequencing rule and provides the basis for the cyclic pathway presented in the following subsection.

The transformation pathway

Before the pathway is specified, its structure may be stated as a whole. Figure 1 presents the framework schematically. Its upper register shows the four complement classes, each paired with the internalisation mechanism derived above. Its centre shows the binding-complement logic, in which a diagnosis for one specific decision selects a single complement as the current constraint and directs effort to that complement alone. Its lower register shows the cyclic migration of the constraint, in which the relief of one complement raises the marginal value of the remaining three and thereby shifts the binding complement to a new position, returning the firm to the diagnostic step for the next decision. The figure is therefore not a maturity staircase but a closed loop with a rotating point of entry, and it should be read in that way.

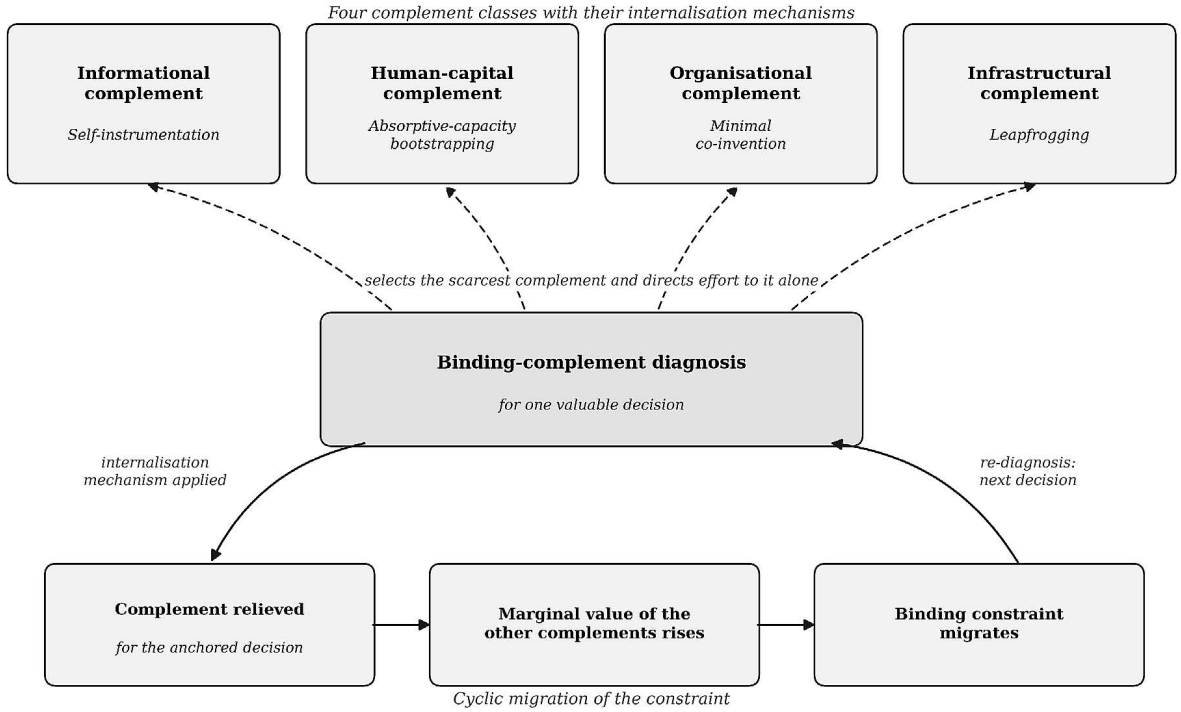


Figure 1. The complement-internalisation framework: four complement classes with their internalisation mechanisms, the binding-complement diagnosis, and the cyclic migration of the constraint

Source: developed by the author

The pathway that the figure formalises was specified as a repeating cycle rather than a staircase, and its stages are logical rather than strictly temporal, so that several may proceed in parallel and the cycle repeats as the binding complement migrates. Each stage is characterised below by its input, the action it requires and the conceptual output it is expected to produce. The pathway opens with the diagnosis of the binding complement. Its input is a single valuable decision that the firm wishes to render data-driven, selected deliberately rather than a general aspiration to digital maturity. The action is an assessment of which of the four complements is most limiting for that decision specifically, framed not as the question of whether the firm is data-mature but as the question of whether, for this decision, the constraint is the absence of data, the absence of the skill to analyse it, the absence of the organisational means to act on it, or the absence of the infrastructure to run it. The expected output is a named binding complement, which directs all subsequent effort and, equally importantly, licenses the firm to defer the other three.

Where the diagnosis identifies the informational complement, as it frequently does at the outset given absent intermediaries and the scale of informality, the pathway proceeds to the manufacture of information through self-instrumentation. The input is the set of interactions the firm already controls, comprising its transactions, its routes, its stock movements and its customer conversations. The action is the conversion of those interactions into structured, recorded observations, undertaken instead of waiting for external data that will not arrive. The expected output is the firm's first proprietary dataset, which is also its first asset that competitors cannot purchase.

The pathway then requires the co-invention of the minimal organisational change, and the analysis established that this stage should be initiated before or alongside any modelling rather than after it. The input is the specific decision identified at diagnosis, together with the person or role that currently makes it. The action is the redesign of the one process, decision right or incentive through which the intended decision will actually change, so that when an analytical result exists a mechanism already exists to act on it. The expected output is an accountable decision rule of minimal scope, and the reason for sequencing it early is to prevent the common failure in which insight is produced but never used because nobody is empowered or obliged to use it.

Bootstrapping absorptive capacity with borrowed knowledge follows. The input is whatever analytical understanding the firm already possesses, however slight, together with the external knowledge it can reach. The action is the cultivation of a small analytical nucleus and the aggressive leverage of external methods, cloud tooling, advisory relationships and machine-learning systems that lower the skill threshold for the task at hand. The expected output is an incrementally enlarged internal knowledge base in which each increment raises the capacity to absorb the next, which is the property that makes the mechanism self-reinforcing rather than merely additive.

Leapfrogging the infrastructure completes the outward arc of the cycle. The input is the technical requirement implied by the decision, sized to that decision alone. The action is the adoption of frugal, mobile-first and cloud-hosted infrastructure, avoiding both the legacy stack and the over-building that would strand scarce capital. The expected output is a technical base adequate to the decision and no larger, which preserves the firm's capacity to redirect resources when the binding complement migrates.

The cycle closes with re-diagnosis. Its input is the relieved complement and the decision now rendered data-driven; its action is the repetition of the diagnostic step for the next decision; and its expected output is a new binding complement, typically different from the last. Relieving one complement raises the marginal value of the others and therefore tends to shift the constraint elsewhere, so that a firm which solves its data problem commonly discovers that the organisational complement now binds. The transformation accordingly advances as a sequence of balanced, decision-anchored increments rather than as a single technological leap.

Three properties distinguish this pathway from the transplanted one, and the analysis established each as a consequence of the governing principle rather than as an independent recommendation. The pathway keeps the complement bundle balanced, so that scarce effort is never stranded against a complement held at zero. It is decision-anchored, so that every increment is tied to a specific decision whose change is observable, which both disciplines scope and generates the evidence that sustains internal support for the transformation. And it is self-propelling, because each relieved complement raises the return to relieving the next, converting transformation from a large and discouraging leap into a series of achievable moves. In development terms, the pathway constitutes a firm-level mechanism for raising the intensity of technology use, which is the margin on which cross-country evidence locates the divergence of incomes (Comin & Mestieri, 2018), by building in sequence the very complementary capabilities whose absence the innovation paradox identifies.

The contrast with the transplanted path clarifies what is at stake. That path is roughly linear and technology-led: assess digital maturity, select a platform, ingest available data, deploy models and scale use cases, drawing throughout on an environment that supplies data, talent and infrastructure on demand. Transplanted into a developing-economy small enterprise, it fails in a characteristic way. The firm acquires capability at the technological margin while the informational, human and organisational margins remain near zero, and because the complements are mutual, the acquired technology delivers little. The firm then concludes, wrongly, that analytics does not work for firms like it, when in fact it has reproduced the productivity paradox at its own scale by investing in an unbalanced complement bundle.

The constraint-to-outcome mapping

The four elements of the framework are brought together in Table 2, which sets out, for each institutional constraint, the current evidence establishing its status, the complement the constraint renders missing, the mechanism by which the firm internalises that complement, the managerial action the mechanism implies and the outcome the analysis expects it to produce.

Table 2. Institutional constraints, missing complements, internalisation mechanisms and expected outcomes

Institutional constraint	Current evidence (source)	Missing complement	Internalisation mechanism	Managerial action	Expected outcome
Thin or absent informational intermediaries; a large share of transactions unrecorded	Informal competition remains a structural feature of the markets faced by formal small and medium-sized enterprises (Amin, 2022); intermediation emerges by substituting verified soft information for absent hard records (Hardik, 2023)	Informational	Self-instrumentation	Instrument the interactions the firm controls, converting points of sale, routes and customer contacts into structured records	A proprietary dataset that cannot be purchased by competitors and that supports one named decision

Table 2. Continued

Institutional constraint	Current evidence (source)	Missing complement	Internalisation mechanism	Managerial action	Expected outcome
Thin and geographically concentrated markets for analytical skills; low prior analytical knowledge	Infrastructural, informational and skills deficits lead the barriers to data-intensive adoption in developing economies (Alalawneh & Alkhatib, 2021); potential absorptive capacity drives strategic flexibility and business-model innovation in smaller firms (Miroshnychenko *et al.*, 2021)	Human-capital	Absorptive-capacity bootstrapping	Cultivate a small analytical nucleus and borrow method, tooling and advisory capacity rather than attempt to hire in a thin market	Incremental internal capability in which each increment raises the capacity to absorb the next
Scarce managerial capital; owner-centric structures without delegated decision rights	Management practice varies widely across firms and countries and accounts for a meaningful share of productivity differences (Bloom & Van Reenen, 2010); top-management support and perceived cost, rather than organisational readiness, determine adoption in emerging-country small enterprises (Shahadat *et al.*, 2023)	Organisational	Minimal co-invention	Redesign the single process, decision right or incentive through which one decision will change, and name the person accountable for it	An accountable decision rule of minimal scope, ready to act on an analytical result when it exists
Uneven last-mile connectivity, power and computation beyond major urban centres	The residual divide is driven by income, capital formation, regulatory efficacy and electricity infrastructure, with cross-border spillovers (Myovella *et al.*, 2021); mobile broadband rather than bandwidth is the channel through which developing economies gain (Bala, 2024)	Infrastructural	Leapfrogging	Adopt mobile-first, cloud-hosted and frugally engineered infrastructure sized to the decision, with a defined fallback for connectivity failure	A technical base adequate to the decision and no larger, preserving capital for the next binding complement

Note: the constraint and evidence columns were compiled from the peer-reviewed studies and statistical reports cited within the table, all published between 2010 and 2025 and selected according to the inclusion criteria stated in the Materials and Methods; the missing-complement, mechanism, action and outcome columns are author-derived outputs of the analytical synthesis and are not attributable to the cited sources
Source: compiled by the author

The illustration below was constructed to demonstrate how the elements established above compose into a single sequence. It is hypothetical in its entirety, refers to no real firm and no real dataset, and reports no numeric results. Its assumptions are stated explicitly and are the author's; the propositions on which its reasoning depends are the literature-supported results established earlier in this section. It demonstrates the framework rather than substituting for it, and no part of it constitutes evidence.

The assumptions are as follows. A mid-sized grocery and general-merchandise retailer is posited, operating a modest number of outlets across a developing economy, with ambitions to move from intuition-led buying and promotion towards analytics-led operation. It is assumed to have a rudimentary point-of-sale system in its larger stores, no external market data of any usefulness, one numerate manager without formal analytical training, and connectivity that is dependable in the capital and erratic elsewhere. These assumptions were chosen because each instantiates one of the four constraints established in the constraint mapping: the absence of purchasable market data instantiates the informational void, the single untrained manager instantiates the thin skills market, the absence of a delegated ordering rule instantiates scarce organisational capital, and the uneven connectivity instantiates the infrastructural constraint.

The transplanted playbook would have this retailer license a business-intelligence platform and a demand-forecasting module and wait for value to appear. Under the analysis established above, it would wait in vain, because it would have invested at the technological margin while the informational, human and organisational margins stood empty, which is the failure mode the complementarity result predicts.

Under the framework, the retailer would begin by diagnosing the binding complement for one valuable decision, taken here to be the quantity of a small set of perishable staples to order for each outlet each week. The diagnosis, following the constraint mapping, identifies the informational complement as binding, because the firm can neither buy demand data nor yet record its own reliably. The retailer therefore self-instruments, turning its point-of-sale terminals and, where those are absent, a simple structured manual count into instruments that produce a proprietary record of sales by outlet and item. In parallel it co-invents the minimal organisational change, adopting a single explicit rule that the weekly order for these staples will follow the analysis rather than the branch manager's habit, with one named person accountable for the decision, so that when a forecast exists a mechanism exists to act on it. It bootstraps absorptive capacity by pairing its one numerate manager with cloud-hosted, low-code forecasting tools and external guidance, keeping the analytical task within reach of a small team. It leapfrogs infrastructure by hosting everything in the cloud and delivering the weekly order recommendations to outlet managers on mobile devices, with a coarse fallback rule for weeks in which connectivity fails, which is the accommodation the evidence on residual infrastructural unevenness makes necessary. Having relieved the informational complement and, minimally, the organisational and infrastructural complements for this one decision, the retailer re-diagnoses and finds that the binding complement has migrated: extending analytics from ordering to promotion now binds on the

organisational complement, because promotion decisions are dispersed across branch managers with no mechanism to coordinate them. The next increment addresses that, and the cycle repeats.

The value of the exercise lies not in any number, none of which is claimed, but in the order of operations the framework imposes. It refuses to let the firm invest in technology ahead of the complements that technology requires, it anchors each step to a decision whose change can be observed, and it advances the transformation as a sequence of balanced moves rather than as a single and probably stranded technological purchase.

DISCUSSION

The theoretical contribution of the study lay in the joining of two literatures that developed apart and in the specification of the construct their junction required. Analytics-led transformation in a developing-economy small enterprise was established as the sequenced internal supply of the complements the environment fails to provide, governed by the discipline that the binding complement, and not the technology, paces the process. This reframes transformation from an act of acquisition into an act of institutional substitution performed at the level of the single firm, and it extends the dynamic-capabilities conception of transformation as continuous renewal developed by D.J. Teece (2007) into an environment where the objects of renewal include assets the firm would ordinarily obtain from outside. The remainder of this section situates that contribution against recent studies not drawn upon in the Introduction, comparing each result with the framework and identifying what the framework adds.

P. Mikalef *et al*. (2020), in research on big-data analytics capability, established that such capability improved competitive performance only indirectly, through dynamic capabilities that in turn strengthened marketing and technological capabilities, with no significant direct effect. The framework agrees with the mediation structure and specifies its precondition. The mediating capabilities that this research measures presuppose an informational base and an organisational apparatus that the surveyed firms possessed; the framework's added value is to describe how a firm assembles those preconditions when the environment does not supply them, which locates the developing-economy problem one step earlier in the same causal chain. An earlier synthesis of case and review evidence by S.F. Wamba *et al*. (2015) reached a compatible conclusion about the organisational conditions under which analytics generates impact, and the framework preserves that conclusion while restricting the conditions under which it can be acted upon.

J. Lin *et al*. (2024), using evidence from firms operating under environmental dynamism, established that big-data analytics capability improved performance indirectly, through proactive and reactive organisational resilience, rather than directly. The framework agrees that the effect of analytical capability is transmitted rather than direct, and its added value is to specify what a firm must internalise before any such transmission can begin. A qualitative study of agrifood small enterprises by R. Cannas (2023) reached a compatible conclusion from the capability side, finding that the decisive capabilities were relational and territorial rather than technical, which the framework accommodates by treating the organisational complement rather than the technological one as the seat of change.

F. Morimura & Y. Sakagawa (2023), using retail-sector evidence, established that both responsive and proactive market orientations raised analytics capability and that capability fully mediated the effect of orientation on firm performance. This result agrees with the framework›s insistence that analytics is a capability rather than a purchase, and it differs from the framework in its implicit assumption that market orientation can be exercised through available market information. The framework's added value in the retail setting, which is the setting of its own illustration, is to specify self-instrumentation as the means by which a firm without purchasable market data constructs the informational base that market orientation would otherwise draw upon.

M. Anwar *et al*. (2024), in work on the antecedents of big-data analytics adoption among small and medium-sized enterprises, examined the relationship between adoption, decision quality and environmental performance. The framework agrees that decision quality is the appropriate proximate outcome of analytics rather than performance measured directly, and it converges with this emphasis through the decision-anchoring property of the pathway. Its added value is to make the decision, rather than the adoption, the unit at which transformation is planned, so that the antecedents of adoption are subordinated to the requirements of a specific decision the firm intends to change.

T. Hongyun *et al*. (2023), using evidence from small and medium-sized enterprises, established that analytics capability moderated the relationships through which digital transformation and digital service capability influenced innovation performance, and that the moderation was not uniformly positive across the relationships tested. The framework agrees that analytics capability operates conditionally rather than universally and differs by supplying an explanation for the non-uniformity: where the complementary bundle is unbalanced, an increment of analytical capability can depress rather than raise performance, because it draws effort towards a margin whose complements are absent. The framework's added value is therefore to predict where such conditional effects should appear.

C.-Y. Chang *et al*. (2025), in a study of digital-transformation anxiety, established that this construct depressed both absorptive capacity and dynamic capability, that both in turn raised digital innovation performance, and that dynamic capability was the stronger mediator. This result agrees with the framework's treatment of absorptive capacity as the operative constraint on the human-capital complement, and it adds a psychological antecedent the framework does not model. Conversely, the framework contributes an explanation for why anxiety should be prevalent in resource-constrained settings: a firm advised to pursue an enterprise-wide, technology-led transformation it cannot resource has good reason for apprehension, whereas the minimality discipline of the pathway reduces the scope of any single commitment to a level the firm can absorb.

A. Tariq *et al*. (2025), in research on digital entrepreneurial firms in a developing country, established that organisational improvisation raised digital innovation

performance, that knowledge-worker productivity mediated the relationship, and that resource constraints weakened it. The framework agrees that improvisation under constraint is productive and differs in the discipline it imposes upon it. Improvisation as measured in that study is unstructured by construction; the framework's added value is to give improvisation a direction, in that the binding-complement diagnosis specifies which margin the firm should improvise at, which is precisely the margin where the study finds resource constraints most damaging.

I.J. Akpan *et al*. (2022), using evidence assembled during the pandemic, established that small enterprises in emerging and developing markets remained largely unreached by cloud computing, big data and predictive analytics, and that the absence of these technologies conditioned their capacity to operate under disruption. The framework agrees with the diagnosis and differs on the inference commonly drawn from it. Where such evidence is often read as a case for accelerating technology adoption, the framework establishes that adoption in advance of complement supply reproduces the failure it is meant to remedy; its added value is to convert an adoption gap into an ordered programme of complement internalisation.

A.A. Oloyede *et al*. (2023), in a systematic review and meta-analysis of digital-economy measurement in developing countries, established that the effects of digitalisation remain poorly quantified because datasets are scarce and definitions vary between countries. This result agrees with the framework's central premise from the measurement side, since the informational void it describes at the level of the firm has an exact counterpart at the level of the national statistical system. The framework's added value is to show that a firm need not wait for the measurement problem to be solved externally, because self-instrumentation produces, for the firm's own decisions, the record that the aggregate system does not yet provide.

A. Nagy *et al*. (2025), using comparative evidence on financial-technology adoption among small enterprises, established that technological and environmental factors significantly influenced adoption while organisational factors did not, and that the pattern differed between a developed and a developing economy, with trust in government contributing to the difference. The framework agrees that the environment carries more explanatory weight in developing settings and differs in its normative implication: whereas the adoption literature treats environmental factors as exogenous conditions to be waited upon, the framework treats the corresponding complements as objects the firm can partially internalise. Y. Liu *et al*. (2025), in research on digital crowdfunding platforms, similarly established that platform-based mechanisms supported the sustainability of small enterprises in emerging markets through entrepreneurial competency, social capital and supply-chain trust, which is consistent with the framework's account of platforms as partial substitutes for missing intermediaries while confirming that the substitution depends on firm-level capabilities the platform does not supply.

T.A. Liedong *et al*. (2020), in a review of the institutional-voids literature, established that the evidence on how voids affect firms' resource commitment in emerging markets remained equivocal, and mapped the conceptualisations, mechanisms and contingencies through which the relationship has been theorised. The framework agrees that the relationship is contingent and offers a specific resolution of part of the equivocation: it predicts that resource commitment under voids is best understood not as a single decision to commit or withhold but as a sequence of commitments ordered by which complement currently binds. J. Pena *et al*. (2020) reported firm-level estimates from eighty-two developing economies that established productivity premiums associated with digital-technology adoption operating jointly with other firm choices, thereby supporting the complementarity premise on which that prediction rests while leaving the ordering question, which the framework addresses, open.

CONCLUSIONS

The study established that analytics-led digital transformation in developing-economy small enterprises was not primarily a technology-acquisition process, but the sequenced internalisation of assets that the external environment did not reliably supply. Four binding complement classes were identified: informational, human-capital, organisational and infrastructural. Mobile connectivity, digital payments and platform intermediation had reduced transaction and connection gaps, whereas deficits in usable data, analytical skills, managerial capital and reliable last-mile infrastructure remained decisive. A corresponding mechanism was specified for each class: self-instrumentation, absorptive-capacity bootstrapping, minimal co-invention and leapfrogging. Their integration yielded the binding-complement principle, according to which the scarcest complement, rather than technological ambition, determined the pace and configuration of transformation. The resulting cyclic pathway required a firm to select one valuable decision, diagnose the complement constraining it, relieve that constraint at the smallest viable scale and repeat the diagnosis as the constraint migrated. The hypothetical illustration demonstrated the logical operation of this sequence without presenting empirical results.

The scientific contribution consisted in joining the complementary-assets and institutional-voids traditions within a single firm-level framework and in explaining the gap between technology access and productive use. For managers and owners, the framework replaced a broad mandate to become data-driven with an ordered diagnostic: begin with one consequential decision, build only the information and capability required for it, make the minimum organisational change needed to act on the analysis, and adopt frugal infrastructure suited to the task. For policymakers, it provided a basis for targeting shared data intermediaries, analytical skills, management practices and reliable connectivity according to the complement that constrained a defined group of enterprises. The study was limited by its conceptual design, the absence of primary empirical data, the heterogeneity hidden by the general category of developing economies and the lack of a validated measure of complement scarcity. Further research should compare complement-internalisation sequencing with technology-led sequencing across matched enterprises, calibrate the framework in specific national and sectoral settings, and develop a measure capable of identifying the binding complement and tracking its migration over time. Such validation would establish when the framework im-

proves decision quality, resource allocation and the sustainability of digital transformation.

ACKNOWLEDGEMENTS
None.

FUNDING
None.

CONFLICT OF INTEREST
None.

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Аналітика цифрової трансформації малих підприємств у країнах, що розвиваються: концептуальна основа інтерналізації комплементарних активів

Анотація. Цифрова трансформація малих підприємств, що ґрунтується на аналітиці, стала центральним інструментом їхнього зростання, однак концептуальні основи, які її описують, майже повністю були розроблені на основі діяльності підприємств у розвинених країнах, де середовище забезпечує більшість активів, необхідних для аналітики. Останні статистичні дані засвідчили, що протягом останнього десятиліття у країнах, що розвиваються, швидко поширювалися підключення до цифрових мереж і цифрові платежі, тоді як системи даних, аналітичні навички та надійна інфраструктура останньої милі – ні. Унаслідок цього малі підприємства опинилися під впливом рекомендацій щодо трансформації, які їхнє інституційне середовище не здатне підтримати. Метою дослідження було розробити концептуальну основу, яка пояснювала б цифрову трансформацію малих підприємств у країнах, що розвиваються, на основі аналітики як послідовну інтерналізацію комплементарних активів, які навколишнє інституційне середовище не змогло забезпечити. Дослідження було проведене у форматі критичного огляду з метою розвитку теорії. Теоретичне ядро було сформоване на основі фундаментальних праць щодо комплементарних активів, абсорбційної спроможності, динамічних спроможностей та інституційних прогалин, а база сучасних доказів за результатами структурованого пошуку в наукових базах даних за 2020-2026 роки, переважно з обмеженням до рецензованих видань і провідних міжнародних статистичних звітів. Формуванню концептуальної основи сприяли чотири аналітичні етапи: картування обмежень, визначення класів комплементарних активів, формулювання основного принципу та визначення траєкторії. У результаті аналізу було виокремлено чотири класи відсутніх комплементарних активів, а саме інформаційні, активи людського капіталу, організаційні та інфраструктурні, і визначено відповідний механізм їхньої інтерналізації: самоінструменталізацію, нарощування абсорбційної спроможності, мінімальне спільне винахідництво та технологічний стрибок. Узагальнення дало змогу сформулювати принцип визначального комплементарного активу, відповідно до якого темп і форма трансформації визначаються не технологічними амбіціями, а найдефіцитнішим комплементарним активом, а також циклічну траєкторію, за якою визначальний комплементарний актив змінюється в міру усунення дефіциту кожного з активів. Запропонована концептуальна основа надає менеджерам діагностичний порядок дій, а політикам – термінологічний інструментарій на рівні підприємства для цілеспрямованого формування заходів на рівні екосистеми. Усі приклади є гіпотетичними, і емпіричні дані не наводилися

Ключові слова: абсорбційна спроможність; динамічні спроможності; самоінструменталізація; технологічний стрибок; інституційні прогалини; комплементарні активи; дифузія технологій

ECONOMICS OF DEVELOPMENT
Journal homepage: https://ecdev.com.ua/
ISSN: 1683-1942
E-ISSN: 2304-6155
Vol. 25, No. 3, 2026
UDC 336.7
DOI: 10.63341/econ/3.2026.22

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Modern banking services and the impact of digitalisation

Abstract. The digitalisation of the banking industry represents a major challenge, closely linked to the growth of financial technologies and customer expectations. The purpose of this paper was to examine the main digital banking services, the key financial technologies that support them and their benefits and challenges for banks and their customers. This study was based on qualitative analysis, literature review and a systematic organisation of information related to modern digital banking services. As a result, eight key digital services that fundamentally changed the customer experience were identified, including online account management, contactless mobile payments, instant transfers, e-wallets, chatbots, online investment and automated budgeting tools. Furthermore, main financial technologies such as artificial intelligence, blockchain, cloud computing, big data and cybersecurity were shown to improve operational efficiency, transaction security and service personalisation. The results showed that the digitalisation of banking services improved accessibility, convenience, financial inclusion and budget optimisation for customers. However, this study also emphasised major challenges related to data privacy, cybercrime, reliance on technology, reduced human interaction and digital isolation. These challenges, combined with sociocultural barriers, prevent 1.3 billion unbanked adults from accessing digital banking services. The practical value of this paper lies in demonstrating the need for banks and financial institutions to invest in secure infrastructure, hybrid solutions combining digital services and human support, and data protection policies that enhance customer trust and improve the stability of digital banking services

Keywords: digital banking; customer experience; fintech; mobile application; financial inclusion

INTRODUCTION

Digitalisation has become one of the main forces driving the evolution of the global banking system. The rise of digital technologies and platforms has greatly changed traditional banking services. Banks are no longer focused solely on traditional banking activities. They are trying to build integrated ecosystems that provide fast, personalised and remotely accessible services. With globalisation and rapid technological progress, modern banking is becoming a customer-centric digital system. It is based on predictive analytics, process automation and smart banking services. The COVID-19 pandemic also played a major role in accelerating the digitalisation of banking services. Health restrictions and the rapid shift to remote work prompted millions of customers to use digital services, electronic payments and mobile applications. These changes increased competition between traditional banks and fintech companies. As a result, banks adopted more ambitious digital transformation strategies to remain competitive and attractive. Banks are investing heavily in advanced cybersecurity systems, robotic process automation (RPA) and open banking solutions. These investments contribute to improved customer service and increased operational efficiency.

Recent studies show that the digitalisation of the banking industry encompasses not only technological improvements but also changes in organisational structures, management and customer relationships. The study by A. Rodrigues *et al.* (2022) highlighted how the integration of artificial intelligence and digital technologies into banking services is reshaping decision-making processes and risk management strategies. The authors argued that banks must

Article's History: Received: 11.02.2026; Revised: 06.07.2026; Accepted: 01.09.2026; Published: 02.10.2026

Suggested Citation:
Mammadli, R. (2026). Modern banking services and the impact of digitalisation. *Economics of Development*, 25(3), 22-31. doi: 10.63341/econ/3.2026.22.

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harmonise technological innovation with data protection to maintain customer trust and the stability of the banking system. This issue is particularly critical in an environment where cyber threats are evolving at almost the same pace as technological innovation. Several recent studies have examined various aspects of the digitalisation of the banking industry. S.K. Singh *et al.* (2024), in a systematic review of trends and challenges in the digitalisation, emphasised the increasing importance of artificial intelligence, blockchain and digital wallets in improving efficiency and expanding financial inclusion. W. Pfoertsch & K. Sulaj (2023) demonstrated that artificial intelligence is essential innovation in payment systems and digital banking services through automation, real-time fraud detection and personalisation of services. H.S. Mamede *et al.* (2023) examined the convergence of AI and robotic process automation in the banking industry. They concluded that this integration could significantly improve banking operations and reduce administrative costs. At the same time, several researchers are expressing concerns about the risks of rapid digitalisation.

According to N. Türegün (2025), the digitalisation of the banking industry is increasing challenges about cybersecurity and data privacy. The researcher highlighted that the integration of open platforms and fintech solutions creates new vulnerabilities that cybercriminals can exploit. Similarly, J.-P. Carrión-Salazar *et al.* (2025) revealed that cyberattacks, phishing and data breaches are major barriers to the adoption of digital services. Other research highlights the increasingly important roles of biometric technologies and artificial intelligence in securing digital banking systems. A. Patil *et al.* (2024) examined the use of biometrics and intelligent fraud detection systems in digital banking services and concluded that these technologies improve transaction security and strengthen customer trust. R. Vedapradha & R. Hariharan (2021) analysed the evolution of banking cybersecurity. They showed that AI and blockchain technologies are becoming important tools for protecting modern banking infrastructure. Recent research also emphasises the strategic importance of generative AI in banking services. According to a study by A. Kovačević *et al.* (2024), banks view advanced AI models as powerful optimisation tools. However, they also recognise them as possible sources of systemic risks and cyber threats. Central banks and regulators are gradually strengthening supervisory mechanisms. Their goal is to increase the digital resilience of the banking sector against emerging technological risks.

Furthermore, A. Demirgüç-Kunt *et al.* (2022) highlighted the fundamental role that digitalisation plays in improving global financial inclusion. Digitalisation has made banking services more accessible to people living in remote areas or regions with limited banking opportunities. They can access these services through smartphones and digital platforms. These advancements not only expand access to banking services but also reduce transaction costs and increase financial transparency. However, despite these benefits, the digital divide, limited technological knowledge and the risk of cybercrime remain serious problems for developing countries. A review of recent academic research showed that most studies focus either on technological innovations in banking industry or on issues related to cybersecurity and digital trust. Studies that comprehensively analysed the impact of digitalisation on modern banking services, considering technical, organisational and security aspects simultaneously, are rare. This gap in academic literature highlighted the importance of this research. The main purpose of this paper was to examine the most widely used digital banking services and technologies in the context of banking digitalisation and to analyse their main benefits and challenges.

MATERIALS AND METHODS

This study employed a descriptive qualitative approach based on a literature review and comparative analysis of secondary data. Its objective was to examine the digitalisation of the banking industry. The research was conducted in several stages. First, relevant literature was identified and analysed, enabling the development of a theoretical framework. Second, digital banking services and the technologies that support them were systematically examined. Third, comparative and qualitative analyses were carried out to assess the benefits, challenges and impacts of digitalisation for banks and their customers. Finally, an analysis of financial inclusion statistics was conducted to identify trends in regions of Africa and Asia regarding access to banking services.

The study used secondary data derived from peer-reviewed journal articles, books, institutional reports, regulatory publications and statistical databases. The primary academic sources were publications indexed in Scopus, Web of Science, ScienceDirect and SpringerLink. The inclusion criteria focused on publications directly addressing modern banking services, the digitisation of the banking sector and digital banking technologies, with preference given to the most recent publications to ensure the relevance and reliability of the analysis. Sources lacking academic or institutional credibility, not directly relevant to the research topic or containing outdated information were excluded. Statistical data were collected from reports and databases published by the World Bank (Demirgüç-Kunt *et al.*, 2022; Klapper *et al.*, 2025), the International Monetary Fund (IMF, 2025), and the European Banking Authority (EBA, 2025). Additional data were obtained from publications by ACI Worldwide (2024), Juniper Research (2024), Deloitte (2022), the IBM Institute for Business Value (IBM, 2026).

The data sources were selected for the period 2018-2026. This period reflects the rapid growth of digital services following the widespread adoption of technologies and digital devices. The following keyword combinations were used for the literature search: "digitalisation", "digital transformation of the banking industry", "financial technologies", "artificial intelligence", "blockchain", "cybersecurity", "mobile banking", "digital payments", "financial inclusion", "unbanked population", "customer experience" and "digital banking services". A comparative analysis was conducted. The main digital banking services were first identified and classified according to their functional purpose. The technologies underlying these services were then comparatively analysed using the following criteria: functional role, practical application in banking, advantages, limitations, and contribution to banking innovation. The qualitative analysis was based on a thematic approach. Data from the literature and selected institutional reports underwent systematic review. The data were coded

according to key research themes, including digital banking services (online and mobile banking), enabling technologies (AI, blockchain, big data and cloud computing), customer behaviour, efficiency, security and privacy, and then combined to identify recurring trends. These trends were related to the implementation of digital banking services, technological innovation, customer behaviour, efficiency and cybersecurity risks. Results from various sources were compared and integrated, leading to a better understanding of the opportunities and challenges associated with the digitalisation of the banking services.

To illustrate the financial inclusion aspect of digital banking services, the study analysed statistical data on the global distribution of unbanked adults. This data comes from the work of S. Burnett (2026) and L. Klapper *et al.* (2025). Rather than conducting a detailed demographic analysis, the study offers a descriptive statistical analysis of the number and regional distribution of unbanked adults worldwide (in regions East Asia, South Asia, Latin America, North Africa and sub-Saharan Africa). In this study, several secondary quantitative indicators were used, such as the number of users of digital banking services and mobile wallets, the volume of real-time payment transactions, the number of unbanked adults, the number of people without internet access. As with all studies based on secondary data, this study had some limitations. It did not include primary empirical data collected directly from banks or customers. In addition, digital technologies, regulatory frameworks and security threats continue to change rapidly. As a result, some findings may become less applicable over time. However, the use of multiple high-quality academic and institutional sources increases the credibility and reliability of the study's findings.

RESULTS

In line with the purpose of this study, the results identified main patterns in the digitalisation of modern banking services. In particular, they highlight the widespread use of digital technologies that are changing how services are delivered. To assess these changes, it is useful to consider the most widely used digital banking services. Online account management enables remote access to core banking functions, including balance and transaction monitoring, personal data management, card control and automated spending notifications via mobile applications. Digital channels handle more than 70% of regular banking activities, which has significantly reduced branch visits and service costs (Klapper *et al.*, 2025). Contactless payments based on Near Field Communication (NFC) technology enable cardless transactions through smartphones and other compatible devices. Mobile payment solutions, including Apple Pay, Google Pay and Samsung Wallet, combine contactless transaction processing with biometric authentication, contributing to shorter processing times and enhanced payment security. By 2024, contactless payments accounted for more than 60% of in-store card transactions in many developed countries. At the same time, the number of mobile wallet users worldwide has exceeded 4 billion (Juniper Research, 2024).

Instant transfers enable funds to be transferred between accounts within seconds, including outside standard banking hours. Compared with traditional transfer methods, which may require several hours or days for settlement, real-time payment systems provide substantially faster access to funds. In many such systems, transactions are processed in less than 10 seconds. Global real-time payment volume exceeded 266 billion transactions in 2023 (ACI Worldwide, 2024). Banks increasingly use AI-powered chatbots to automate routine customer support functions. These systems provide information on account-related matters, assist with basic service requests and explain banking procedures. Their continuous availability enables banks to reduce customer waiting times and improve the efficiency of service delivery. According to IBM (2026), AI-powered chatbots can resolve approximately 70-80% of routine customer enquiries without human intervention, potentially reducing customer service costs by up to 30%. Online investment services provide customers with direct access to financial markets through mobile applications and web-based platforms. These services support transactions involving stocks, bonds and other financial instruments and may incorporate analytical tools and automated advisory systems, including robo-advisors, to support investment decision-making.

Banking applications increasingly incorporate spending analysis and budgeting tools that support personal financial management through automated transaction categorisation and expenditure monitoring. Some applications also provide notifications when predefined spending limits are exceeded or when substantial payments are anticipated. More broadly, the digitalisation of banking services has transformed the ways in which customers manage financial transactions and interact with financial institutions. Continued investment in digital technologies reflects banks' efforts to improve operational efficiency, maintain competitiveness and enhance the accessibility and quality of service delivery. Artificial intelligence is one of the most widely used technologies in the banking industry. By leveraging AI, banks can automate various tasks, such as responding to customer inquiries, analysing financial data, and detecting fraudulent activity (Horobets *et al.*, 2025). AI is also used to assess credit risk by predictively analysing borrowers' financial behaviour. Banks use algorithms that can identify suspicious transactions in real time to prevent bank fraud. According to EBA (2025), AI-based fraud detection systems can achieve accuracy rates exceeding 90%. These applications can contribute to higher operational efficiency and lower service-related costs. Table 1 summarises the main areas of AI application in banking and their effects on financial institutions and customers.

Table 1. Application of AI in banking services

Feature	Description	Impact
Customer inquiries	Instant response AI chatbots	Reduced average response times (e.g., from minutes to seconds), increased first-contact resolution rates and improved customer satisfaction
Fraud detection	Real-time monitoring of transactions	Improved fraud detection efficiency, reduced false positive rates, reduced financial losses from fraudulent transactions and accelerated detection

Table 1. Continued

Feature	Description	Impact
Credit risk assessment	Predictive borrower analysis	Improved forecasting accuracy, reduced loan default rates and more consistent loan approval decisions
Operational efficiency	Automation of repetitive tasks	Reduced transaction processing time, lower manual workload, reduced operational costs and increased employee productivity

Source: prepared by the author based on A. Rodrigues *et al.* (2022) and H. Horobets *et al.* (2025)

Blockchain is a secure and transparent technology for storing and transmitting information. It is mainly used in banking to increase transaction security and reduce the need for intermediaries. Since all blockchain transactions can be verified and are extremely difficult to change, the risk of fraud is lower. Figure 1 shows the structure of blockchain technology. This technology also makes international money transfers faster and cheaper. In addition, blockchain increases customer trust and strengthens the competitiveness of banks by increasing the security and traceability of financial transactions (Tsai *et al.*, 2024).



Figure 1. Blockchain structure

Source: prepared by the author

Cloud computing enables banks to manage and store data on remote servers accessible via the internet. This technology offers great flexibility and reduces the cost of maintaining traditional IT infrastructure. It is estimated that cloud computing can reduce IT operating costs by approximately 40-45%. It also improves system scalability and service availability (Fig. 2). As a result, banks can process large amounts of data in real time and quickly adjust capacity as needed (Cheng *et al.*, 2022).

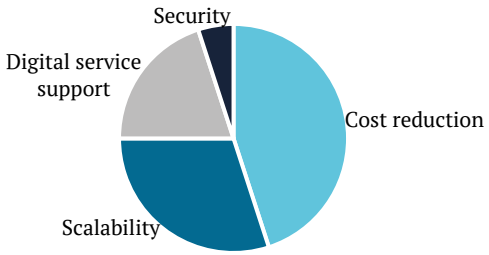


Figure 2. Distribution of the benefits of cloud technologies in the banking sector

Source: prepared by the author based on A. Muduli & A. Choudhury (2026) and S.E. Lolemo & H.B. Pandya (2025)

Cloud technologies support the development and delivery of digital banking services, including mobile banking applications and online payment platforms. Their adoption can improve the scalability, processing efficiency and flexibility of banking operations. From a security perspective, cloud service providers employ data protection and cybersecurity mechanisms intended to safeguard customer information and maintain service reliability. Mobile banking applications represent a widely used channel for remote access to banking services, enabling functions such as fund transfers, bill payments and account monitoring. These applications enhance service accessibility by allowing customers to perform routine banking operations remotely and outside traditional branch hours. Figure 3 shows the distribution of usage of main mobile banking features. In 2024, the number of mobile banking users worldwide exceeded 3 billion (IMF, 2025). Customer satisfaction is also consistently higher among active mobile banking users than among customers who mainly use branch services. Banks also use real-time notifications to inform customers of transaction status and enhance security. Banks like Revolut and Starling have integrated budgeting tools into their apps to help customers manage their spending more effectively. Mobile banking increases customer satisfaction and loyalty by offering fast and easily accessible services (Nandy *et al.*, 2026).

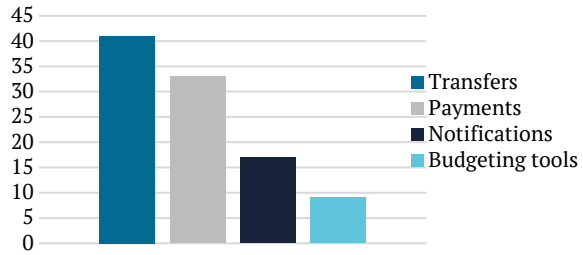


Figure 3. Mobile banking features usage in 2025 (%)

Source: prepared by the author based on L. Klapper *et al.* (2025) and S. Burnett (2026)

Big data is a technology that leverages vast amounts of data to derive strategic and valuable insights. In the

banking industry, big data helps analyse customer behaviour and personalise banking products (He *et al.*, 2023). This allows banks to offer products tailored to the individual needs of each customer. Figure 4 shows the characteristics of big data.

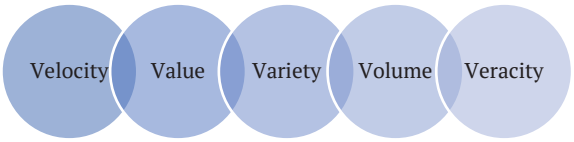


Figure 4. Characteristics of big data
Source: prepared by the author based on W. He *et al*. (2023)

Data analytics also helps detect financial risks and fraud by identifying unusual patterns. For example, banks can detect suspicious credit card transactions and block them immediately. Big data improves banks' decision-making, risk management and competitiveness. With the development of digital banking services, cybersecurity has become a major priority for banks. Biometric authentication methods such as facial recognition, fingerprint recognition and voice recognition enhance the security of user authentication. These methods are more secure than traditional passwords, because passwords can be stolen or hacked (Kaixiang *et al.*, 2024). Banks also use advanced encryption systems to protect sensitive customer data. For example, the banking applications of HSBC and Barclays require two-factor authentication before approving high-value transactions. By using these technologies, banks reduce the risk of cyberattacks and strengthen customer trust in digital banking services. Table 2 provides a detailed classification of the features of cybersecurity technologies.

Table 2. Features of cybersecurity technologies

Security feature	Description	Benefit
Biometric authentication	Facial, fingerprint, voice recognition	Increased authentication success rates, reduced account takeovers, fewer password reset requests and shorter user login times
Encryption	Protection of sensitive data	Reduced customer data breaches, lower unauthorised access and improved compliance with data protection regulations
Two-factor authentication	Verification of high-value transactions	Reduced unauthorised transaction rates, increased securely authenticated transactions, increased customer trust and reduced fraud-related losses
Cyberattack protection	Advanced monitoring and response	Reduced cybersecurity incidents, reduced mean time to detection and response to attacks, reduced financial losses from cyber incidents and improved service availability

Source: prepared by the author based on A. Kovačević *et al*. (2024) and N. Türegün (2025)

The cybersecurity measures presented in Table 2 play distinct but interdependent roles in digital banking services. Biometric and two-factor authentication primarily ensure access control and user authentication. These mechanisms enable customer identity verification and reduce the likelihood of unauthorised access to accounts and transactions. Encryption technologies protect sensitive information by preventing unauthorised disclosure and mitigating the risks associated with data breaches. Cybersecurity measures focus on the detection, prevention and response to cyber threats, enabling financial institutions to identify and address potential attacks more efficiently. Together, these technologies form a multi-layered approach to digital banking security, contributing to improved protection of financial data, reduced exposure to cyber risks and enhanced reliability of digital services.

Digital financial technologies provide many benefits to banking customers. One of the main benefits is accessibility. Through banking mobile apps and websites, customers can check their account balances, send money and pay utility bills anytime, anywhere. This is especially convenient for residents in rural areas with few bank branches. This eliminates the need for long trips to the nearest bank branch. Furthermore, digitalisation makes banking services more accessible to people with mobility difficulties or time constraints (Ananda *et al.*, 2020). Digital technologies make banking services far more convenient and faster. Customers no longer have to wait in long lines for simple banking tasks. Transactions can be completed in seconds, even on weekends and public holidays. Studies show that digital banking transactions typically take less than a minute. Similar transactions completed at a bank branch often take 15-30 minutes, including waiting times (Deloitte, 2022). This enhances the customer experience and saves time in daily life (Müller *et al.*, 2024).

Digital banking services leverage data and artificial intelligence to provide personalised services and products to customers. Banking applications can analyse spending habits and recommend solutions tailored to each user's needs. For example, they can send notifications if a customer exceeds their monthly budget. They can also provide personalised savings plans to help customers reach their financial goals. Banking platforms such as Monzo and Bank of America also offer automated advice on spending and investing. This personalised approach helps customers manage their finances more effectively and increases their trust in banking services. Automated payments are another important advantage of digital banking services. Customers can schedule recurring payments such as utilities, rent and monthly fees. This eliminates the need to enter payment details manually every month. Automated payment systems significantly reduce missed payments and improve on-time bill payments for both households and businesses. Businesses also benefit from this feature, processing payroll and supplier payments quickly and securely (Daoud & Anaya, 2025).

Digital banking services play an important role in financial inclusion. They provide banking services to people who were previously excluded from the traditional banking services. Mobile payment services have enabled millions of people in Asia and Africa to make transactions, save money and receive financial assistance. This convenience has supported economic development and reduced social inequality. It has also facilitated access to loans and

banking services tailored to the needs of enterprises, as well as self-employed individuals. According to the World Bank, by 2021, approximately 79% of adults worldwide had a banking account (Demirgüç-Kunt *et al.*, 2022). In Sub-Saharan Africa, mobile money accounts have become a main financial service for hundreds of millions of adults. Although the number of adults with bank accounts continues to grow globally, it is estimated that in 2024, approximately 1.3 billion adults worldwide still lacked bank accounts and direct access to modern banking services. The vast majority of these individuals live in developing countries (Klapper *et al.*, 2025). According to the reports of L. Klapper *et al.* (2025) and S. Burnett (2026), Figure 5 illustrates the demographic proportion of unbanked adults in the regions of East Asia, the Middle East, South Asia, Latin America, North Africa and sub-Saharan Africa.

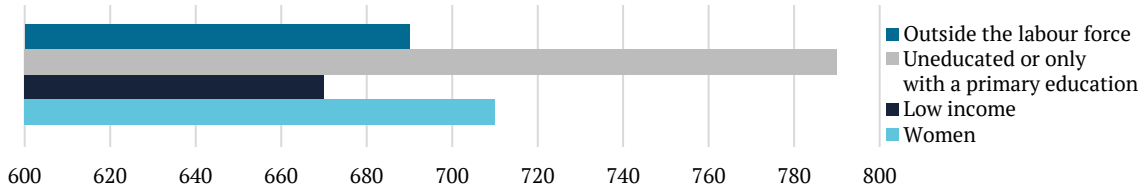


Figure 5. Demographic proportion of unbanked adults (in millions)
Source: prepared by the author based on L. Klapper *et al.* (2025) and S. Burnett (2026)

Barriers to accessing digital banking services show broad similarities across regions; however, the predominant constraint varies by regional context. These include the limited availability of digital banking service providers in African countries, socio-cultural restrictions on women's access to mobile phones in Middle Eastern countries, low-income levels in South Asian countries, and inadequate digital infrastructure in rural areas across these regions. While digitalisation of banking services offers many benefits, it also creates significant challenges for banks and customers. Security is one of the biggest issues in digital banking services. Cybercriminals use various methods, including malware, phishing and hacking, to steal money and personal information (Asmar & Tuqan, 2024).

Banks continue to report that phishing is one of the main causes of digital banking fraud. Although the use of multi-factor authentication has significantly reduced account takeover fraud, it still accounts for a large proportion of reported cyber incidents. For example, customers may receive fake messages that appear to come from their banks. These messages can lead to the theft of their login information. Attacks on banking systems can cause significant financial losses and disrupt operations. To reduce these risks, banks invest heavily in data encryption, two-factor authentication and fraud detection systems. Digital banking services collect vast amounts of personal and financial data. This includes customer identity, spending habits and transaction records. Storing so much sensitive information in one place increases the risk of data misuse and leakage. Furthermore, some companies may use customer data for commercial or advertising purposes without sufficient transparency. Therefore, banks must develop strong data protection policies and comply with privacy regulations (Barjaktarović Rakočević *et al.*, 2023).

Banking operations are becoming increasingly dependent on digital infrastructure and IT systems. This dependence can cause problems when technical failures, network outages or software errors occur. For example, in January 2025, Barclays experienced a major IT outage that lasted for more than two days. Many customers were unable to access online banking services, make payments or complete transactions. During the same period, customers could not receive their salaries on time. This outage also occurred during the UK tax return deadline and affected thousands of users. (Reuters, 2025). In February 2025, Halifax and Bank of Scotland experienced another outage. This disrupted mobile banking and payment services for several hours. As a result, customers were unable to transfer money or access their accounts (Makortoff & Banfield-Nwachi, 2025). These incidents show that over-reliance on technology can increase operational risks. It can also expose banks to service disruptions and cyberattacks targeting servers and payment systems (Sharma, 2025). Therefore, investment in backup systems, regular updates and business continuity plans is essential for banks and financial institutions.

As digital banking services become more widespread, direct contact between customers and bank employees is gradually decreasing. While mobile banking applications are convenient, they cannot always replace the human support needed for complex transactions such as mortgages and financial advice. For example, older adults and those unfamiliar with digital tools may find it difficult to resolve issues using only chatbots and automated services. The reduction in human interaction can make some customers feel isolated and dissatisfied (Ghosh & Golder, 2026). Therefore, banks need to maintain a balance between automation and personalised service. The digital divide is a significant social challenge in the development of digital banking services. In particular, the elderly, people living in rural areas and low-income groups do not always have access to the internet or the necessary digital devices. In accordance with International Telecommunication Union (2024), an estimated 2.6 billion people worldwide still did not have access to the internet in 2024. This has limited their ability to access digital banking services. Physical bank branches are gradually closing around the world, forcing customers to use unfamiliar digital tools. This situation risks exacerbating social and economic inequalities. Overall, the findings show that digitalisation has reshaped banking services and brings many benefits for both banks and customers. At the same time, these advantages are accompanied by major challenges. These include security threats, privacy concerns, dependence on technology, unequal access to digital services and reduced human support. The results show that the long-term success of

digital banking services depends on striking the right balance between technological innovation and security, reliability and effective management of customer support. This will help ensure that digital banking services remain efficient, secure and accessible to all users.

DISCUSSION

The results of this study demonstrate that digitalisation has greatly altered modern banking services. It has improved accessibility, increased transaction speeds and provided a more personalised customer experience. Analysis of various banking and financial services reveals that digital technologies have become central to financial institutions' strategies. These findings support several recent studies on banking innovation and the digitalisation of banking services. A. Muduli & A. Choudhury (2026) found that the use of digital technologies significantly improves the efficiency and competitiveness of banks. Furthermore, the authors emphasised that even small banks can compete with larger banks through the digitalisation of their services. These findings are consistent with the results of this study, which show that digital services enable banks to provide faster and more accessible services to a wider range of customers.

Similarly, S. Kamboj *et al.* (2022) investigated mobile banking platforms. They found that always-on access to banking services improves customer satisfaction. Their study notably emphasised the convenience of mobile apps and the speed of banking transactions. This is especially evident when looking at services that make everyday banking easier, including instant transfers and payments. A study by S.E. Lolemo & H.B. Pandya (2025) focused on the quality of digital banking services from a customer perspective. The authors showed that ease of use, security and customisation are the most important factors in assessing digital banking services. The results of this study support these findings. They show that banks can use artificial intelligence and big data tools to provide personalised services tailored to individual customer needs.

Furthermore, D. Kang & N. Shin (2026) examined how customers view digital banking services. Their research revealed that customers particularly value the stable availability, ease of use and speed of online services. However, the researchers emphasised that concerns about cybersecurity and limited digital skills are major barriers to the adoption of digital services. These observations are consistent with the findings of this study regarding risks associated with security, privacy and the digital divide. A study by N. Del Sarto *et al.* (2025) focused on the relationship between traditional banks and fintech companies. The authors revealed that banks are collaborating with technology companies to accelerate digitalisation and improve banking services. The study also confirmed that technologies such as e-wallets, online platforms and mobile applications are essential elements of the modern banking industry.

M. Shabir *et al*. (2023) conducted a study during the COVID-19 pandemic. Their study revealed that this health crisis increased the use of mobile banking applications and digital payments. The authors highlighted reliability, speed and performance as the main reasons for customers to adopt digital banking services. This analysis confirms the findings of this study that customers prefer services that are fast, accessible and always available. From a technical perspective, T. Felipe *et al.* (2026) investigated the impact of main digital innovations on the banking industry. Their research revealed that these technologies improve data management, security and overall efficiency within banks. The results of this study are follow the same pattern, highlighting the role of AI in fraud detection, blockchain in ensuring security and cloud computing in developing digital services.

Z. Yu & J. Liu (2025) explored the digitalisation of banking services from a risk management perspective. Their research revealed that digital technologies help reduce fraud, improve regulatory compliance and make financial transactions efficient. These results are consistent with the findings of this study, particularly regarding the importance of cybersecurity, biometrics and fraud detection systems. Finally, the study of G. Osuma (2025) on financial inclusion in African countries revealed that digitalisation improves access to banking services for people in rural areas and previously excluded from the banking system. This study supports the important role of technologies in reducing financial inequality. However, as many researchers have reported, limited internet access, low literacy and economic constraints continue to hinder full financial inclusion. Overall, the reviewed research confirms that digitalisation is an important milestone in the development of the global banking industry. Digital technologies significantly improve operational efficiency, service quality and customer experience. At the same time, this evolution also creates considerable challenges such as cybersecurity, data protection, technology dependency and digital exclusion. Therefore, banks must continue to invest in technological infrastructure, security and digital education programs. These efforts are necessary to achieve a secure, sustainable and inclusive digital transformation.

CONCLUSIONS

Digitalisation has made banking services faster, more accessible and more customer-centric. The findings of this study showed that main digital banking services included online account management, mobile banking applications, contactless payments, instant money transfers, digital wallets, AI-powered chatbots, online investment platforms and automated budgeting tools. They allowed customers to access banking services anytime, complete transactions faster, manage their finances more easily and improve access to banking services for both individuals and businesses. The study identified AI, blockchain, big data analytics, cloud computing and biometric authentication as key technologies driving digitalisation in banking services. AI improves customer service, helps detect fraud and supports credit risk assessment. Blockchain makes transactions more secure and transparent. Big data analytics help banks deliver personalised banking services. Cloud computing gives banks greater operational agility. It also allows them to develop digital banking services more quickly. Biometric authentication increases security by providing a more secure way to verify customer identity.

While digital banking offered many benefits, the study also identified several important challenges. The main risks included cybersecurity threats such as phishing, malware, hacking and fraud. There were also privacy concerns associated with banks collecting and processing large amounts of personal and financial information. Other risks

included reliance on digital technologies, which can lead to service disruptions if systems fail. The decline in face-to-face interactions in customer service was another concern. In addition, the digital divide can prevent the elderly, people living in rural areas and other digitally disadvantaged groups from accessing banking services. These findings highlight the need for continued investment in security, data protection, digital infrastructure and digital inclusion programs. Such efforts will help ensure that everyone can benefit from digital banking services. Future research should explore how emerging technologies such as decentralised finance and next-generation artificial intelligence will impact the future development of banking services. It should also examine their implications for customer trust, financial inclusion and banking regulation.

ACKNOWLEDGEMENTS
None.

FUNDING
None.

CONFLICT OF INTEREST
None.

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Сучасні банківські послуги та вплив цифровізації

Анотація. Цифровізація банківської галузі являє собою серйозний виклик, тісно пов'язаний зі зростанням фінансових технологій та очікувань клієнтів. Метою цієї статті було дослідження основних послуг цифрового банкінгу, ключових фінансових технологій, що їх підтримують, а також їхніх переваг і викликів для банків та їхніх клієнтів. Це дослідження базувалось на якісному аналізі, огляді літератури та систематичній організації інформації, пов'язаної із сучасними послугами цифрового банкінгу. В результаті було визначено вісім ключових цифрових послуг, які принципово змінюють досвід клієнтів, включаючи онлайн-керування рахунками, безконтактні мобільні платежі, миттєві перекази, електронні гаманці, чат-боти, онлайн-інвестиції та автоматизовані інструменти бюджетування. Крім того, показано, що основні фінансові технології, такі як штучний інтелект, блокчейн, хмарні обчислення, великі дані та кібербезпека, покращують операційну ефективність, безпеку транзакцій та персоналізацію послуг. Результати показали, що цифровізація банківських послуг покращує доступність, зручність, фінансову інклюзію та оптимізацію бюджету для клієнтів. Однак це дослідження також підкреслило основні проблеми, пов'язані з конфіденційністю даних, кіберзлочинністю, залежністю від технологій, зменшенням взаємодії з людьми та цифровою ізоляцією. Ці виклики, у поєднанні із соціально-культурними бар'єрами, перешкодили 1,3 мільярду дорослих, які не користуються банківськими послугами, отримати доступ до цифрових банківських послуг. Практична цінність цієї статті полягає в демонстрації необхідності для банків та фінансових установ інвестувати в безпечну інфраструктуру, гібридні рішення, що поєднують цифрові послуги та людську підтримку, а також політики захисту даних, що підвищують довіру клієнтів та покращують стабільність цифрових банківських послуг

Ключові слова: цифровий банкінг; клієнтський досвід; фінтех; мобільний застосунок; фінансова інклюзія

ECONOMICS OF DEVELOPMENT

Journal homepage: https://ecdev.com.ua/

ISSN: 1683-1942
E-ISSN: 2304-6155

Vol. 25, No. 3, 2026

UDC 339.162.3
DOI: 10.63341/econ/3.2026.32

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Wartime effects on food consumer behaviour and purchasing patterns in Ukraine

Abstract. The purpose of the study was to analyse changes in food consumer behaviour as a result of the Russian-Ukrainian war and identify the main factors of these changes. The study used a complex of general scientific methods, including observation, analysis and synthesis, generalisation, comparison, and induction. The results showed that despite the transformation of Ukraine's food supply system during the war, consumer activity remained relatively stable, which is due to the resilience and adaptability of the domestic agricultural sector to the challenges of wartime. It has been established that economic instability, security risks and psychological factors are the main factors determining consumer decisions in times of crisis. During wartime, these factors took on new forms and have a greater effect on consumer behaviour. It has been found that the impact of the COVID-19 pandemic and the war in Ukraine has a cumulative effect of negative shocks. The growth in the popularity of online grocery shopping and the involvement of new consumer groups in digital commerce were noted. The dynamics of Ukrainians' purchasing activity in the food segment were analysed. Trends in the popularity of online grocery shopping were studied and described in relation to consumers' main socio-demographic characteristics. It was proven that the worsening security situation has led to a reassessment of consumer priorities and a redistribution of household expenses. At the same time, traditional dietary habits have undergone changes, which has affected the structure of diets and everyday eating patterns of the population. The peculiarities of nutrition of different groups in Ukrainian society at the beginning of the full-scale invasion, and the psychological factors influencing consumer behaviour, were described. The phenomenon of panic buying during crises and the increased orientation of consumers towards

Article's History: Received: 18.03.2026; Revised: 03.08.2026; Accepted: 01.09.2026; Published: 02.10.2026

Suggested Citation:
Dyman, T., Zadorozhna, R., Dyman, N., & Mazur, T. (2026). Wartime effects on food consumer behaviour and purchasing patterns in Ukraine. *Economics of Development*, 25(3), 32-45. doi: 10.63341/econ/3.2026.32.

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domestic brands, especially those that support the Armed Forces of Ukraine and socially vulnerable categories of the population, were investigated

Keywords: food market; war in Ukraine; panic buying; rationalisation of consumption; food security; crisis conditions

INTRODUCTION

The protracted war in Eastern Ukraine, coupled with russia's full-scale invasion on February 24, 2022, has posed a variety of challenges to Ukrainian society. The loss of territories, forced migration of the population, large-scale destruction of production, energy and logistics infrastructure, disruptions in the supply of goods, narrowing of sales markets, rising inflation rates and falling purchasing power of the population have formed a complex of factors that worsen the socio-economic situation in the country. Ukrainian food and agricultural enterprises located in or near combat areas were forced to suspend their operations or relocate. One of the problems had become the destruction of storage facilities for grain and other agricultural goods, particularly in the south of the country. Food imports have been complicated by the blockade of sea trade routes and limited access at border checkpoints with neighbouring countries. These events had far-reaching consequences for Ukrainians in particular, significantly changing their consumer behaviour.

The transformation of consumer behaviour in times of crisis was actively studied by scientists, as it allowed to understand the mechanisms by which society adapts to extreme challenges. The COVID-19 pandemic was a prime example of how global cataclysms are catalysing a fundamental shift in consumption patterns. S. Aday & M.S. Aday (2020) examined the impact of the pandemic on the food supply chain and found that it affected every stage, from production to consumption. The authors demonstrated that restrictions on movement and business closures resulted in significant changes in consumer demand. These changes included a shift in emphasis from public catering to home cooking, as well as the emergence of the phenomenon of excess purchases of basic products due to uncertainty about the future. S.M.Y. Arafat *et al.* (2020) analysed 214 media reports on panic buying during the pandemic and concluded that the media had played a significant part in spreading fear and anxiety. Researchers pointed out that images of empty supermarket shelves and the spread of remorse on social media encouraged people to stockpile supplies irrationally, which has only exacerbated shortages.

The researchers O. Bochko & N. Kozhushok (2021) examined how consumer needs had changed during the pandemic in the context of Maslow's hierarchy. The authors revealed that people's priorities shift towards basic physiological needs and safety under conditions of risk, with self-expression taking a back seat. Instead, digitalisation has become a critical driver of change for manufacturers, forcing them to adapt to the new reality through situational marketing and the online market. M.C. Espinoza *et al.* (2021) analysed shopping behaviour in the context of choosing between online and offline purchases during the pandemic. The researchers discovered that Internet proficiency and the ability to quickly obtain product information were key factors influencing people's decision to switch to online shopping. At the same time, it was found that consumers still find the reliability, quality and speed of purchasing goods from traditional stores attractive.

The transition from the pandemic crisis to full-scale war in Ukraine has caused even deeper changes in the economic environment and public consciousness. A. Zhuk & Y. Pavelko (2024) analysed how the cumulative impact of the pandemic and russian aggression, as global catastrophes, affected the behaviour of Ukrainian online shoppers. According to the authors, in conditions of economic instability and risks to life, consumers prioritise health, access to essential goods, and safety, including cybersecurity. The war forced consumers to limit spending on entertainment, but it increased demand for high-quality and affordable domestically produced goods that ensure autonomy and survival in extreme conditions. T. Dyman *et al.* (2024) found that, despite the initial irrational demand, the Ukrainian agrarian system and logistics had demonstrated high resilience and adaptability in the face of wartime risks. The authors investigated the phenomenon of panic shopping as a psychological mechanism that enables people to regain control in high-risk situations. Scientists' analysis of patriotic motives as a leading factor in the modern consumer behaviour of Ukrainians showed that citizens have a positive attitude towards domestic brands and tend to choose Ukrainian-made food products in order to support domestic producers.

O. Dluhopolskyi & N. Bilovus (2024) identified the main factors influencing consumer behaviour under martial law, determining that security, economic instability and psychological stress were the most significant. Researchers pointed to a sharp decline in consumer sentiment at the beginning of the invasion. This was later replaced by a gradual adaptation: consumers have become more cautious in their spending, started to avoid public places, and begun reallocating their budgets to prioritise essential goods. The trend towards more conscious and thoughtful choice of goods was confirmed by the study by O. Bulyk & I. Havryliuk (2023). The authors observed that consumers are shifting away from luxury items and expensive purchases in favour of promotions, discounts and Ukrainian brands. This change in consumer behaviour became a way to support the national economy during the war. Thus, analysis of the sources shows that consumer behaviour during wartime is mainly dependent on economic constraints, pragmatic considerations, psychological adaptation and patriotic motives. However, existing studies of Ukrainian behaviour in the food market during wartime crises lack a comprehensive study of how economic, security, and psychological factors interact to shape new consumer priorities and purchasing patterns, and a systemic understanding of how these changes occur. The purpose of this study is to examine the impact of military events on consumer behaviour in the Ukrainian food market and to analyse the key factors contributing to these behavioural changes.

MATERIALS AND METHODS

The methodological framework of this study was based on secondary data analysis combined with a review of scholarly publications by Ukrainian and international researchers exploring the determinants of consumer behaviour during crisis and wartime conditions. Secondary data sources were integrated to provide a comprehensive and multidimensional analysis of food market dynamics during the full-scale invasion of Ukraine by the Russian Federation. Secondary data sources utilised in the study included official information from Ukrainian government agencies, data from national and international marketing research agencies, including Deloitte (2023; 2024a; 2024b, 2026), Gradus (2024a; 2024b; 2024c), and Retail Association of Ukraine (Jermakova & Symonenko, 2023), on consumer sentiment, purchasing trends and changes in eating habits among Ukrainians amid the full-scale war. The study was grounded in previous research examining changes in consumer behaviour under extreme conditions, particularly during the COVID-19 pandemic (Arafat *et al*., 2020; Ben Hassen *et al*., 2020; Espinoza *et al*., 2021). It also considered studies analysing consumer behaviour changes during the war in Ukraine (Bulyk & Havryliuk, 2023; Gudz, 2023; Dluhopolskyi & Bilovus, 2024). Where applicable, data from consumer surveys and regional monitoring reports were incorporated to supplement the quantitative evidence base.

The analysis focused on four macro-regions of Ukraine (Northern, Southern, Eastern and Western), as well as the city of Kyiv. The selection of materials was based on their relevance to the research topic. In particular, sources that highlighted changes in consumer behaviour during wartime were analysed. The analysis covered data from 2022 to 2025. The study employed a combination of qualitative and quantitative analytical methods selected in accordance with the objectives of the research. Qualitative analysis was used to systematise and summarise information regarding the nature and causes of changes in consumer behaviour in Ukrainian food market, as well as to identify recurring behavioural patterns, motives and key trends described in the examined sources. Descriptive methods were applied to characterise the current state of food security in Ukraine during the wartime period, enabling a structured overview of the key institutional, economic, and social dimensions of the problem. Formalisation and generalisation techniques were used to systematise the available empirical evidence and derive broader conclusions regarding the transformation of consumer behaviour patterns under crisis conditions.

Analytical and synthetic approaches underpinned the identification and classification of the primary determinants of consumer decision-making in the food market during armed conflict. These methods facilitated the decomposition of complex behavioural phenomena into constituent factors – including economic instability, security concerns, and psychological variables – and their subsequent integration into a coherent analytical framework. In order to quantitatively examine the impact of war on food consumer behaviour and purchasing patterns, a set of indicators was used, including the following: indicators of offline and online food purchasing activity among Ukrainians (share of consumers, average check, frequency of purchases per month); share of online food buyers by main demographic and social characteristics (gender, age, place of residence); total monthly spending on online food purchases for different consumer groups (people who did not change their place of residence; internally displaced persons; people who moved abroad, and those who returned from abroad). To analyse changes in these indicators over time, measures of the intensity of dynamics and structural shifts were applied. The absolute change (AC) in the share was calculated using formula:

$$AC = di_1 - di_0, \quad (1)$$

where di_1, di_0 – shares of the particular parts of the structure in the compared periods, %. Total monthly spending of online food buyers (S) was defined according to formula:

$$S = C \times F, \quad (2)$$

where C – average online check (UAH), F – average frequency of online purchases per month. Tabular and graphical methods were employed throughout the study to visualise key findings, illustrate structural relationships, and present temporal trends in an accessible and reproducible format. All data processing and visualisation were performed using Microsoft Excel.

The study of changes in the nutritional habits of Ukrainians since the start of the war was conducted, identifying the following groups: Ukrainians under occupation; internally displaced persons; residents of relatively "safe regions" who did not change their place of residence; servicemen of the Armed Forces of Ukraine and Ukrainians who have moved abroad. These groups were categorised based on the differences in their life circumstances, as well as the extent to which the war had disrupted their established food consumption patterns. The identified features of food consumptions were then systematised and grouped according to the aspects of consumptions affected, enabling group-specific patterns to be recognised. The combination of these complementary methodological approaches ensured both the internal validity of the analytical framework and the broader applicability of the findings to the study of consumer behaviour in conflict-affected food markets. The main methodological limitation was that the data obtained from surveys can lead to discrepancies between subjective consumer assessments and objective indicators, such as average check or frequency of purchases. When answering questions, survey participants relied on their own perceptions and assumptions, which can significantly affect overall spending statistics. Another limitation was the influence of the respondents' psychological state. The results of surveys conducted during the war can be distorted because people are in a state of heightened anxiety, fear, and stress, which directly affects their answers. In addition, the duration of crisis periods causes a "memory effect": it becomes difficult for consumers to accurately compare their current habits with those before the war began.

RESULTS AND DISCUSSION

Economic and security challenges as drivers of consumption change

An important determinant of consumer behaviour under martial law is economic instability, as armed conflict is

typically accompanied by a decline in economic activity and investment, increased inflation, and rising unemployment. These factors contribute to decreased household incomes, altering consumer behaviour. Notably, the gross harvest of all crop groups exceeds domestic consumption needs by a factor of 1.5 to 3. Additionally, the domestic demand for meat and meat products is fully met. In 2022, the per capita consumption of meat and meat products in Ukraine was 53.1 kg, consistent with the level observed in 2021 (53 kg) (Minagro: Ukraine will have..., 2022). Despite substantial losses in the sector and a contraction of the domestic dairy market due to large-scale migration abroad, the dairy industry continues to meet domestic demand. In 2022, the per capita milk consumption was estimated at 199 kg (Infagro, 2022). According to the Association of Milk Producers, total milk production in 2022 declined by 12.1%, amounting to 7.66 million t, compared to 2021 figures (Linetska, 2023). These outcomes could have been significantly worse; however, the effective functioning of dairy farms in relatively safer regions and the relocation of livestock from conflict-affected areas helped mitigate overall losses. In particular, central and western regions of Ukraine demonstrated increased milk production, driven by the relocation of enterprises and heightened demand for raw materials. For instance, milk production rose by 23.4% in the Chernivtsi region, 21.5% in the Ternopil region, and 8.4% in the Vinnytsia region (Zhurakovska, 2023).

Ukrainian demand for fruit and berry crops is fully met. Although 25% of berry plantation areas and 20% of orchard areas were lost due to the war, Ukraine remains a net importer of fruits and berries (The National Council for the Recovery of Ukraine from the Consequences of the War, 2022). The Vinnytsia, Chernivtsi, Khmelnytskyi, Dnipro, Lviv, and Poltava regions – key producers of fruits and berries – are fully capable of satisfying national demand for these products. Despite the loss of over 40% of commercial onion production and approximately 30% of commercial carrot production due to the partial occupation of several regions, there is no shortage of vegetables in the country. To mitigate the risk of deficits in essential vegetable crops, the area under cultivation for "borscht set" vegetables has been expanded in western and central Ukraine. This measure aims to compensate for the decline in production resulting from the temporary occupation of southern territories (Zhurakovska, 2023).

Regarding the quality of the Ukrainian population's diet, it was considered low even prior to the outbreak of war. A long-standing issue in Ukraine has been the discrepancy between actual meat and meat product consumption and the rational intake level of 80 kg per person, as recommended by the Ministry of Health of Ukraine in accordance with national dietary guidelines based on physiological needs for essential nutrients and energy (Order of Ministry of Health of Ukraine No. 1073, 2017; Poruchinska *et al.*, 2022). The supply of fish and seafood products has traditionally been inadequate and heavily reliant on imports. The war and the imposition of martial law have further exacerbated this situation: approximately 80% of aquatic bioresource users have either completely or partially ceased commercial fishing operations. As of August 1, 2022, the catch of aquatic bioresources had declined by more than 60% compared to the same period in 2021 (State Fisheries Agency of Ukraine, 2022). There is a growing risk of further deterioration in the quality of the population's diet, primarily due to a significant increase in food prices and declining economic accessibility. As of December 2022, compared to December 2021, the consumer price index for various food products increased substantially (%): eggs – 176.6; fruits – 173.8; vegetables – 151.8; fish and fish products – 145.8; sugar – 131.0; bread and bakery products – 130.3; butter – 128.9; pasta – 127.9; hard and soft cheeses – 125.0; meat and meat products – 124.6; milk – 118.7; sunflower oil – 114.5 (Zhurakovska, 2023).

The primary drivers of these price increases include the rising cost of agricultural production, largely attributed to higher prices for fuel, lubricants, and fertilisers, as well as increased food storage expenses. Additionally, at the end of 2022 and the beginning of 2023, widespread energy disruptions caused by the targeted shelling of Ukraine's energy facilities and infrastructure further aggravated the situation by undermining the operational stability of agricultural enterprises. Under such circumstances, ensuring the sustainability of agricultural production and maintaining the efficiency of the production-processing-storage-distribution chain is of critical importance. It is noteworthy that Ukraine's food distribution logistics system successfully withstood extreme pressure, demonstrating both social and economic resilience. Food shortages were limited to specific items – such as cereals, canned goods, and salt – and occurred primarily during the initial 1 to 1.5 months of the conflict, after which the supply chain was fully restored. In 2022, the food logistics and supply chains experienced a territorial realignment across the southern, eastern, western, and central regions of the country. Restructuring efforts continued into 2023 (Bulyk & Havryliuk, 2023; Zhurakovska, 2023).

Despite the ongoing war, 95 new retail outlets belonging to chain retailers were opened in Ukraine between February and July 2022. Of these, more than 63% were established in the western regions, 18% in the northern regions, and another 18% in the central and southern regions. The ATB grocery chain alone opened 12 new stores. Fozzy Group, operating under the Silpo brand, completely shifted its expansion strategy to the western regions, where it opened 78 new stores in the first five months of the war (Jermakova & Symonenko, 2023). Thus, while Ukraine's food supply system has undoubtedly undergone changes during the war, the consumer activity of the population has not experienced significant disruption. This stability can be attributed to the high resilience and adaptability of the Ukrainian agricultural sector in the face of wartime challenges. Despite inflation, loss of production capacity, and logistical problems, the lack of a deeper decline in consumer activity in Ukraine during the war is a combination of adaptive behavioural reactions, state support, international assistance, and the peculiarities of the country's economic structure (shadow economy, informal markets, and mutual aid networks, etc.), which is generally consistent with some cases in other conflict regions, but differs from classic economic crises.

Structural shifts in consumer priorities

The full-scale war has substantially reshaped established patterns of food consumption and purchasing behaviour

among Ukrainians. Analysts from the Retail Association of Ukraine (RAU) and Num8erz have presented noteworthy findings regarding changes in Ukrainian consumer behavior during the war. Their study encompassed major supermarket chains such as Novus, Varus, Spar, and Nash Krai, as well as market networks like Domashniy Market and LotOk, which collectively reported a turnover exceeding UAH 65 billion in 2023. The analysis was based on data from 300 million customer receipts, including information linked to more than 2.5 million loyalty cards (Jermakova & Symonenko, 2023). Research has demonstrated that Ukrainian consumer behaviour in the food segment underwent significant changes in 2023 – the first full year of war – compared to the pre-war year of 2021. Notably, shifts in product category demand were observed. As in the pre-war period, dairy products, dry groceries, bread, beverages, vegetables, and fruits continued to account for approximately 40% of the consumer basket. However, the largest share of spending – over one-third – was directed toward alcohol, vegetables and fruits, sweet groceries, tobacco products, and dairy products.

Purchases of eggs increased by 21%, reflecting their role as an affordable source of protein. Similarly, purchases of cooking-related products rose by 19%. Consumption also increased for bakery products, sweets, tobacco products, processed meat, alcoholic beverages, dairy products, and soft drinks. In contrast, there was a decline in the consumption of vegetables and fruits, dry groceries, fish, cheese, and low-alcohol beverages – a trend observed uniformly across all regions of Ukraine. The decrease in demand for vegetables is attributed primarily to their high cost, rather than the influence of martial law. Over the first 10 months of 2023, vegetable prices increased by 81% compared to the same period in 2021. At the same time, soft drinks, despite a 58% price increase, saw their share in the consumer basket grow by 14% (Jermakova & Symonenko, 2023). In quantitative terms, dairy products remained the top-selling category in 2023. Compared to 2021, the structure of consumption within this category has not undergone significant changes. However, a clear trend has emerged toward the preference for long-shelf-life products. In particular, sales of ultra-pasteurised milk have increased, while sales of regular pasteurised milk have declined by approximately 15% (Jermakova & Symonenko, 2023; Gradus, 2024c).

In 2023, a notable shift occurred in consumer perceptions of product pricing. Specifically, the proportion of price-sensitive consumers decreased by 6%, while the share of individuals who pay little attention to price when making purchases increased. These changes were particularly evident among those who had previously considered price to be of utmost importance – their share declined from 28% to 23%. Regionally, the number of price-sensitive consumers increased in both the eastern regions and the capital. This may be attributed to the influx of internally displaced persons to Kyiv and its surrounding areas, which likely influenced the rise in the proportion of consumers seeking to economise on food. The eastern regions present the most contrasting dynamics: a high percentage of consumers reporting efforts to save on food (24%), alongside the highest share of consumers who are not sensitive to prices (20%). Overall, across all regions of Ukraine, consumers in 2023 reported spending less cautiously on food compared to the post-COVID year of 2021 (Jermakova & Symonenko, 2023).

The increase in food prices in 2024 has led consumers to adopt more cautious and cost-conscious strategies in meeting their dietary needs. According to Gradus (2024c) research conducted in October 2024, 64% of respondents reported switching to cheaper food products; 48% indicated that they cook at home more frequently; 42% stated that they had reduced their overall food consumption, and 27% admitted to skipping meals. Additionally, 21% of respondents reported an increase in the purchase of semi-finished food products. The tendency to economise on food expenses is most pronounced among older adults: 77% of respondents aged 56 and above reported the need to save money when purchasing food. Overall, in 2024, 67% of Ukrainians had to limit their food expenditures (Fig. 1). The highest restrictions are in the southern and central regions; the lowest are in Kyiv and western Ukraine.

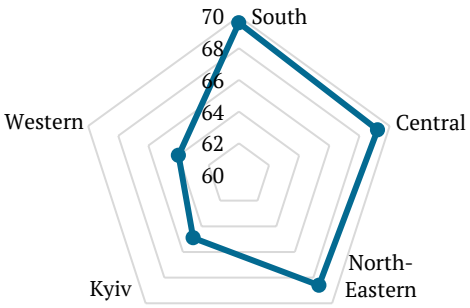


Figure 1. Share of respondents who reduced spending on food in 2024, by region of Ukraine, %
Source: compiled by the authors based on Gradus (2024c)

Purchases of confectionery and fish and seafood products have decreased among 49% and 48% of respondents, respectively. The most "protected" items in household consumer budgets include bread, oil, flour, cereals, vegetables, and eggs – only 11% of Ukrainians reported economising on these products. The war in Ukraine has also caused food prices to rise in other countries. A study by K.G. Grunert *et al.* (2023) found that people in ten European countries were also faced with rising prices for the majority of food categories. This prompted them to change their behaviour with regard to food, making them more frugal and aware. The main strategies of European consumers in this situation were to reduce consumption, find cheaper alternatives, or avoid overly expensive products. Experts identify security as one of the key determinants of consumer behaviour under martial law. The ongoing war has heightened the population's sense of threat. Concerns over personal safety and the well-being of family members significantly influence purchasing behaviour. According to a survey conducted by Deloitte, since the beginning of the full-scale invasion, 11% of respondents have suffered physical injuries, 52% have experienced moral or psychological harm, and 32% have sustained material or property losses (Deloitte, 2024b). Consequently, the decline in personal security has led to a shift in consumer priorities and a redistribution of household expenditures. Consumers tend to avoid public spaces where the risk of terrorist attacks is elevated and may opt for more expensive goods if they perceive the purchasing process to be safer.

Following the COVID-19 pandemic, the war has not only reinforced the need for physical distancing – by accelerating the transition of many activities to the online environment – but has also highlighted, on a much broader scale, the importance of sustainability and the preservation of living standards for future generations. Security threats have restricted the mobility of large segments of the population, heightened uncertainty about the future, and disrupted established consumer behaviours and decision-making patterns. Consumer behaviour has evolved: individuals have recognised the advantages of engaging in various activities within the online environment. They are now able to shop more conveniently from the comfort of their homes, thereby saving time previously spent on in-person shopping. Moreover, there is a growing emphasis on spending quality time with family and friends, as well as an increased interest in mental, physical, and creative development. Consumers are also showing greater concern for ethical purchasing practices. The virtual space, enabled through diverse digital platforms, offers enhanced convenience for shopping – further amplifying the importance of ethical considerations in consumer behaviour (Zhang *et al.*, 2019; Daroch *et al.*, 2021).

According to Kantar, which analysed changes in the purchasing behaviour of Ukrainians between May and August 2022, nearly 94% of Ukrainians have experience with online shopping. Notably, 14% made their first online purchase only after the onset of the war. Researchers emphasise that the war achieved what the COVID-19 pandemic could not – it drew in individuals who had previously avoided e-commerce. One of the key drivers behind this shift is the desire to save money, as many consumers believe that prices on online platforms are lower than in physical stores. At the same time, 76% of Ukrainians who shop online reported that they have begun ordering less frequently due to financial constraints caused by the war (Stasyuk, 2022). By 2024, the average transaction value for online and offline food purchases had returned to pre-war levels. Compared to the period before 24 February 2022, average consumer spending on online purchases increased by 57.6% in 2025, exceeding the growth observed in offline grocery retail (47.7%). However, in terms of purchase frequency, offline shopping continues to dominate (Table 1).

Table 1. Purchasing activity of Ukrainians in the food segment before and after the full-scale invasion

Indicator	Until 24.02.2022	2022	2023	2024	2025
Share of Ukrainians (%) who buy: ■ offline ■ online	 n/a n/a	 n/a n/a	 99 40	 98 35	 98 42
Average check, UAH: ■ offline ■ online	 864 1,080	 798 1,322	 885 824	 1,032 1,273	 1,276 1,702
Frequency of purchases during the month, times ■ offline ■ online	 16.8 2.3	 15.3 0.8	 16.2 1.3	 15.3 1.2	 14.9 1.6

Source: Deloitte (2023; 2024a; 2024b; 2026), authors' calculations

The most popular food items purchased by Ukrainians online during the war are water, eggs, bread, buckwheat, dairy products, sugar, potatoes, chicken, pasta, and bananas. These are the products regularly ordered by more than half of the customers of the online service Zakaz.ua, which delivers products from leading supermarket chains throughout Ukraine (Focus.ua, 2023). The availability of mobile applications by major food market players also significantly contributes to the popularisation of online commerce due to the simplicity and convenience of placing orders, free delivery, and additional promotions and cashback from sellers. COVID created a digital infrastructure and a habit of online shopping, while the war changed the functional meaning of the online channel – from a channel of convenience, it partially turned into a channel of accessibility, security, and adaptation of consumption to an unstable environment. And that is why the combination of a higher average check with a lower frequency is very indicative: online shopping becomes more rational, planned, and targeted, while offline retains the function of regularly providing everyday needs. At the same time, the trend did not disappear after the acute phase of the war: in 2025, Ukrainians were already using online shopping, delivery, and ATMs more often, but basic needs were still mostly met offline. An analysis of the socio-demographic profile of Ukrainian online food shoppers shows that it has changed significantly during the war (Table 2).

Table 2. Dynamics of the share of online food buyers by demographic and social characteristics for the period 2022-2025

Groups of online shoppers	Share, %				Absolute change in share, p. p.	
	2022	2023	2024	2025	2025 to 2022	2025 to 2024
Gender						
Men	35.9	39.9	38.0	41.0	5.1	3.0
Women	34.4	39.8	33.0	42.0	7.6	9.0
Age						
18 – 27	37.9	49.2	42.0	48.0	10.1	6.0
28 – 42	39.3	42.1	42.0	49.0	9.7	7.0
43 – 57	30.9	35.7	38.0	38.0	7.1	0.0
58 and older	14.3	21.5	35.0	30.0	15.7	-5.7

Table 2. Continued

Groups of online shoppers	Share, %				Absolute change in share, p. p.	
	2022	2023	2024	2025	2025 to 2022	2025 to 2024
Place of residence						
Did not change their residence place	35.3	38.2	32.0	39.0	3.7	7.0
Internally displaced persons	31.3	40.6	35.0	37.0	5.7	2.0
Moved abroad	35.9	29.1	49.0	53.0	17.1	4.0
Returned from abroad	n/a	49.2	45.0	53.0	n/a	8.0

Source: Deloitte (2023; 2024a; 2024b; 2026), authors' calculations

In 2023, the proportion of men and women making online food purchases was nearly equal: while in 2022 the share of male shoppers exceeded that of female shoppers by 1.5 percentage points (p. p.), in 2023 this difference narrowed to just 0.1 p. p. However, in 2024, the proportion of both genders preferring online food shopping declined. The share of male online shoppers dropped by 1.9 p. p. compared to 2023, while the share of female shoppers declined by 6.8 p. p. As a result, in 2024, men once again had a higher representation among online food buyers, similar to the situation in 2022. Compared with 2024, the share of women increased significantly by 9 p. p. in 2025. Accordingly, the difference in the proportion of male and female buyers was reduced to just 1 p. p. In terms of spending, the average transaction amount for men in 2024 reached UAH 1,235 (Deloitte, 2024a), reflecting an increase of UAH 272 or 28.2% compared to 2023. Despite the decline in the share of women engaging in online grocery shopping in 2024, their average transaction value increased even more significantly – by UAH 577 or 78.6%. In 2025, intensification of women's consumer activity was reflected in the fact that the average transaction value of their online purchases rose to UAH 2,193 (Deloitte, 2026). Thus, the increase for women was UAH 882 (67.3%), compared with UAH 256 (20.7%) for men.

Regarding age demographics, it was expected that younger age groups would dominate online shopping activity. However, the most notable growth occurred among the oldest consumer group. In 2023, the share of online shoppers aged 58 and older increased more than 1.5 times, rising from 14.3% in 2022 to 21.5%. In 2024, this growth continued, increasing by a factor of 1.63 to reach 35.0%. Although the proportion of online shoppers in the oldest age group declined to 30% in 2025, this segment demonstrated the most substantial progress in adopting online food shopping. A similar, albeit less pronounced, upward trend was observed among people aged 43-57, with the share of online shoppers in this group increasing by 7.1 p. p. between 2022 and 2024 to 38% and remained at that level in 2025. The 28-42 age group has shown the most stable upward trend in terms of its share of online shoppers, rising from 39.3% in 2022 to 49.0% in 2025. Despite the high proportion of online shoppers among the youngest consumers, this group cannot be described as particularly consistent in their attitudes towards online shopping. After a substantial rise in the proportion of 18-27-year-olds buying groceries online in 2023 (49.2%), this indicator fell to 42.0% in 2024 before rising again to 48.0% in 2025.

The increase in online shopping participation among people aged 58+ during the war is explained by several factors. Older audiences, who may have previously been less involved in e-commerce, were forced to reorient themselves to online channels during the pandemic and war due to mobility restrictions, health and safety risks. The war exacerbated these factors, forcing older people to use online stores more actively as a safe way to obtain necessary goods. The dynamics of youth are unstable, as this category is more flexible and tends to change their consumer habits depending on the circumstances. Young people often choose different purchasing channels (offline, online, social networks), their online shopping may fluctuate due to link problems, financial instability or a reorientation to savings. In addition, young people may turn more to temporary promotions, which also affects the volatility of dynamics. The difference in the dynamics of men and women is due to socio-role and behavioural factors. Women are traditionally more responsible for household purchases, so in crisis situations they are more actively switching to online shopping to maintain access to the necessary goods. Men may make certain categories of purchases more often or stick to their usual channels to a greater extent, which creates differences in the growth rates of online activity. From a geographic perspective, in 2023, the most active online shoppers were Ukrainians who had returned from abroad – nearly every second respondent in this category reported buying food online. Among respondents who had moved abroad or returned from abroad in 2025, more than half were online grocery shoppers – 53% in both groups.

During 2022-2023, internally displaced persons also actively embraced remote food purchasing, with the share of those utilising this option increasing by nearly 30% in 2023. In 2024-2025 the proportion of this group stabilised at more than one-third of IDPs. The smallest shift in 2023 compared to 2022 was observed among those who had not changed their place of residence, with an increase of just 2.9 p. p. The indicator fell to 32% in 2024, but then rebounded to 39% in 2025. Conversely, the share of Ukrainians who remained abroad and purchased groceries online declined by 6.8 p. p. in 2023. Nonetheless, this group exhibited the highest average food expenditures compared to other population categories based on place of residence during the period 2023-2024 (Fig. 2). In 2023, Ukrainians abroad were the leaders in terms of the average check amount in 8 categories out of 20 surveyed, with the largest amount of spending in both online and offline stores on food (Deloitte, 2024b). In 2024, this was the only category of Ukrainian citizens for which the share of online shoppers rose sharply compared to 2023. In contrast, all other groups experienced a decline in the proportion of online food shoppers: among Ukrainians who returned from abroad, the share decreased by 4.2 percentage points; among internally displaced

persons (IDPs), by 5.6 p. p.; and among those who did not change their place of residence, by 6.2 p. p. – the largest decline observed in 2024. In 2025, the portion of people shopping for groceries online increased across all surveyed groups, with the largest increase (8 p. p.) observed among those who had returned from abroad.

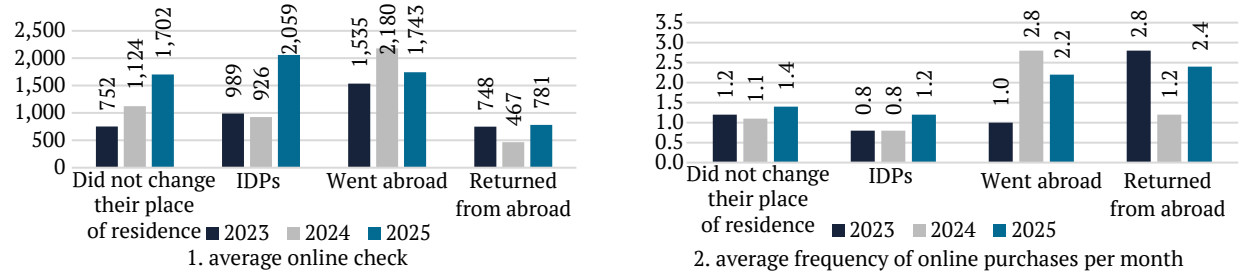


Figure 2. Purchasing activity of Ukrainians depending on their place of residence in 2023-2025
Source: compiled by the authors based on Deloitte (2024a; 2024b; 2026)

The average transaction value from 2023 to 2025 rose steadily for Ukrainians who did not change their place of residence. For internally displaced persons and those who had returned from abroad, this figure decreased in 2024, but then rose again in 2025. However, the intensity of these trends differed significantly between the two groups (Fig. 2). For IDPs, a slight decrease (by 6.4%) was followed by rapid growth (by 122.4%), whereas for those who had returned from abroad, the decline in 2024 was 37.6%, followed by a rebound of 67.2%. As a result, in 2024, the average amount spent by Ukrainians abroad on online food purchases was 2.35 times higher than that of IDPs and 1.94 times higher than that of individuals who had not changed their place of residence. For comparison, in 2025, these ratios were 0.85 and 1.02 times, respectively. Thus, Ukrainians abroad were the only group to experience a decline in average spending, while IDPs and those who remained in Ukraine showed stable growth, which accelerated in 2025. The average amount spent by those returning from abroad is the lowest and most volatile. After declining in 2024, it remained below the 2023 level despite a partial recovery in 2025. This group is also characterised by high purchase frequency, and the trend of this indicator is similar to that of the average online check. The average frequency of online purchases made by Ukrainians abroad rose sharply in 2024 (from 1.0 to 2.8) and then declined slightly in 2025 (to 2.2). This fact can indicate an adjustment in consumer behaviour abroad. To provide an overall assessment of consumer activity among the study groups, the total monthly online spending on food was calculated (Table 3).

Table 3. Dynamics of the total monthly spending of online food buyers for the period 2023-2025

Groups of online shoppers	2023	2024	2025	Growth rate relative to the 2023, %
Did not change their residence place	902.4	1,236.4	2,382.8	164.1
Internally displaced persons	791.2	740.8	2,470.8	212.3
Moved abroad	1,535.0	6,104.0	3,834.6	149.8
Returned from abroad	2,094.4	560.4	1,874.4	-10.5

Source: Deloitte (2024a; 2024b; 2026), authors' calculations

According to Table 3, internally displaced persons are the most dynamic group. Starting in 2023 from the lowest level of total monthly spending on online food purchases (UAH 791.2), they had risen to second place in 2025 (UAH 2,470.8) with the highest base-period growth rate (212.3%). This suggested gradual economic stabilisation and adaptation of IDPs. The difference in total monthly online spending on food between the IDP group and those who did not relocate gradually narrowed from UAH 111.2 in 2023 to 88.0 in 2025, with the IDP group's figure exceeding by 3.7%. This shift occurred due to a simultaneous increase in both the average online check and the average frequency of online purchases of IDPs in 2025. This indicates an adaptation and convergence of this group's consumption levels with those of the rest of the population. Online expenditure data from those who have returned from abroad shows volatile and generally negative trends. This can reflect difficulties with reintegration upon return, such as a temporary loss of income or unstable employment. Starting in 2024, Ukrainians living abroad lead in terms of total online-spending on groceries. However, the decline in 2025 reflects not a steady upward trend, but rather higher income levels or prices in their countries of residence.

Psychological adaptation and panic buying

Psychological aspects are an important determinant of consumer behaviour. Stress, anxiety, and uncertainty associated with martial law certainly affect buyers' decisions and consumer sentiment. Some customers may feel the need for relaxation and psychological support, while others may refuse to splurge and focus on necessary and important expenses. The suddenness of the russian invasion disrupted the established gastronomic practices of Ukrainians and significantly changed their eating behaviour. One part of the population found itself in a situation of resource shortage, while the other part did not lose access to food, but the usual daily patterns and diets changed (Fig. 3).

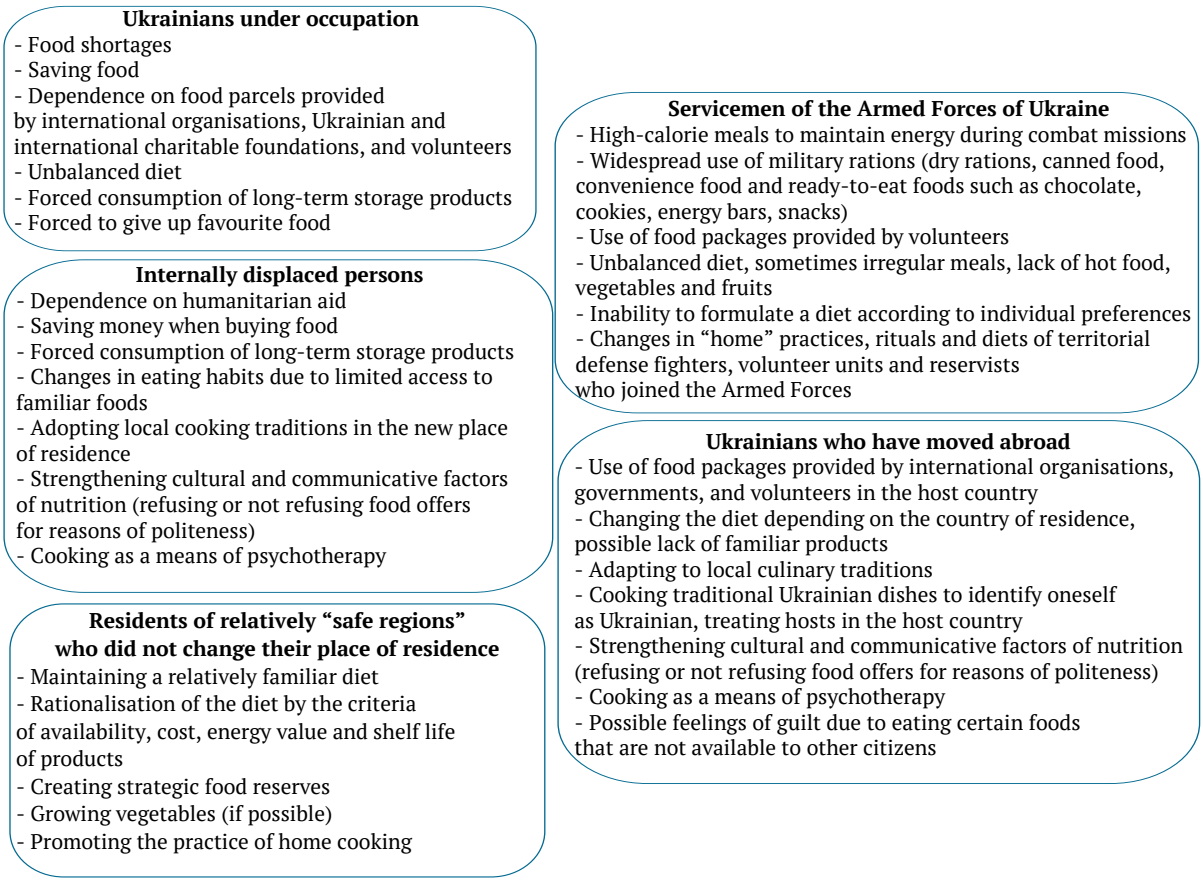


Figure 3. Peculiarities of Ukrainian nutrition depending on life circumstances at the beginning of the full-scale invasion (February-May 2022)

Source: compiled by the authors based on their own observations and A. Petrenko-Lysak (2022)

Despite the variability in individual circumstances among Ukrainians – such as their geographic location at the onset of the war, age, social status, and financial situation – the majority have deprioritised concerns related to "healthy" eating, food quality, and personal gastronomic preferences in response to life-threatening stress and restricted access to food products. Under such conditions, the role of food has been largely reduced to fulfilling basic energy requirements necessary for sustaining bodily function. Eating disorders – including loss or increase of appetite, diminished enjoyment of food, alcohol abuse, and heightened consumption of coffee and energy drinks due to fear of falling asleep – were especially pronounced during the initial days of the war and were observed across all regions, irrespective of their proximity to active combat zones (Petrenko-Lysak, 2022). As a result, consumption of specific food categories increased, which was likely due to increased levels of consumer anxiety. These behavioural changes appear to serve as coping mechanisms intended to mitigate psychological pressure and ease existential distress. The studies of L. Larson & H. Shin (2018) and T. Ben Hassen *et al*. (2020) have indicated that fear can trigger irrational and atypical purchasing behaviour, exemplified by the phenomenon of "panic shopping", characterised by impulsive and excessive purchases (Wang & Hao, 2020). For example, during the COVID-19 pandemic, panic buying, stockpiling of food, and, as a result, empty shelves in stores were quite common even in developed countries (Arafat *et al*., 2020).

One of the most widely accepted psychological explanations for panic buying is that stockpiling food provides individuals with a sense of control in the face of a high-risk situation caused by a disaster (Yuen *et al*., 2020). When confronted with stress or adverse events, individuals seek to restore a sense of equilibrium and manage the emotional impact of the situation. As a result, they may experience a sudden compulsion to accumulate food out of fear of potential shortages or anticipated price hikes. Consumers have turned to panic buying as a coping strategy to mitigate feelings of uncertainty and reassert control over their environment. This behaviour is closely associated with the scarcity effect: when basic food items become scarce, the tendency to hoard intensifies. The perceived insecurity fuels further attempt to secure provisions, often resulting in frenzied and irrational stockpiling behaviour, as noted by D. Šálková *et al*. (2023).

In a survey conducted to study the behaviour of Danish and British shoppers in the early stages of the COVID-19 pandemic, J. Dammeyer (2020) found that only four out of ten shoppers did not make additional purchases. The author also discovered that consumers who panic-buy food can gradually develop a long-term addiction in the form of compulsive buying behaviour. M.S. Müller *et al.* (2026) analysed panic buying during the pandemic and the war

in Ukraine, disproving the hypothesis that consumers had adapted or become more resilient. The researchers found that experiencing a previous crisis did not reduce the tendency to panic shopping, but on the contrary, increased expectations of shortages and perceptions of general threat. This indicates the cumulative nature of negative shocks, which accumulate and reinforce each other, increasing buyers' subjective feeling of vulnerability.

The social phenomenon of panic consumer behaviour deserves increased attention from Ukrainian researchers, as stressful situations in Ukrainian society do not stop, and the period of transformation has stretched for decades. Ukraine's economic growth, backed by borrowed funds, when the population gained some freedom of consumption, quickly gave way to the depreciation of the hryvnia and the economic crisis, which prompted most people to resort to consumer minimalism. This forces the population to form consumption patterns that will at least enable them to survive (Dyman *et al*., 2024). The full-scale war has become a challenge for Ukrainian society, causing the highest level of stress and uncertainty. Under such circumstances, safety and security considerations are the main motivating factors in decision-making. Individual strategies for finding the best response to a crisis situation are further strengthened by the "crowd effect": having no experience in war, people rely on the "collective mind" and other people's experience. Thus, in the first days of the war, Ukrainians emptied the shelves of grocery stores and supermarkets in a state of shock, and production and supply of food to the retail network was suspended for some time. The irrational rush for food, especially in regions far from the war zone, created temporary imbalances in supply and demand (Gudz, 2023). According to research conducted by Deloitte (2023; 2024b), in 2022, 80% of Ukrainians maintained strategic food stocks and 58% continued to replenish them, whereas in 2023, the proportion of consumers making strategic food purchases fell to 47%. After coping with the stress of the outbreak of war, many Ukrainians experienced the psycho-emotional effect of eating their favourite and festive food. The restoration of typical consumer practices related to the selection, purchase, and consumption of food products contributed to the formation of the effect of relative normalisation and the reproduction of pre-war models of everyday life.

Growing popularity of local brands

At the onset of the war, during a period characterised by heightened uncertainty, Ukrainian consumers primarily focused on stockpiling essential food items, largely disregarding product brands. However, over time, information about the manufacturer has emerged as a significant determinant in purchasing decisions. The proportion of respondents who consider brand identity when making purchases increased from 54% in December 2022 to 62% in March 2024 (Gradus, 2024b). According to a study conducted by Gradus (2024a) research in April 2024, 86% of Ukrainians reported a positive attitude toward domestic producers. The food sector, in particular, demonstrates the highest level of consumer loyalty: 90% of respondents indicated a preference for Ukrainian-made food products, while only 15% favoured imported alternatives. The predominant motivations behind this behaviour are rooted in patriotic sentiment – 59% of respondents chose domestic products to support local producers, and 57% to contribute to the national economy. Simultaneously, the affordability of Ukrainian goods was cited as a decisive factor by 50% of consumers. The observed preference for Ukrainian-made products should therefore be interpreted as a hybrid form of wartime consumer behaviour, combining conventional economic considerations with patriotic consumption. While affordability remains an important determinant of choice, the stronger influence of motivations related to supporting domestic producers and the national economy indicates that consumer preferences increasingly incorporate civic and solidarity-oriented values. Thus, during wartime, country of origin may function not only as a market attribute but also as a symbolic and socially embedded component of consumer value.

It should be noted that Ukrainian brands have received support from more than just domestic consumers. As A. Josiassen *et al.* (2024) have shown, the concept of "place solidarity" has a direct impact on international consumer behaviour in the context of the Russian-Ukrainian war. The authors found that solidarity with Ukraine, which arises as sympathy through observing the suffering of the people, acts as a powerful driver of boycotting the goods of the aggressor country and stimulates the willingness to buy and recommend Ukrainian products. The authors found that solidarity with Ukraine, which arises from sympathy for the suffering of its people, is a powerful driver of boycotting goods from the aggressor country, and stimulates the willingness to buy and recommend Ukrainian products. The researchers analysed the formation of such a position and found that the key motivators of solidarity are the perception of realistic and symbolic threats to humanity as a whole. Therefore, consumer activity in times of war is not only determined by negative sentiments towards the aggressor, but also by the constructive force of solidarity and consumers identifying with the affected party as part of their "ingroup". There has also been a notable increase in consumer preference for brands engaged in supporting the Armed Forces or assisting socially vulnerable populations. Some companies are actively involved in charitable initiatives, including the provision of food supplies to military personnel, healthcare workers, children, and the elderly (Khemiy, 2022; CSR Ukraine, n.d.; Oliynyk & Latkovska, 2023).

Conversely, Ukrainian consumers exhibit a high level of sensitivity toward unethical advertising practices. Marketing campaigns that exploit military themes for promotional hype or manipulative purposes are generally perceived negatively (Osiik, 2024). Currently, the principle of "Each one to his own for his own!" – a concept rooted in the Ukrainian cooperative movement of the nineteenth century – is experiencing renewed relevance (Ethnohouse, 2016). This principle encapsulates the values of solidarity and mutual responsibility in supporting local producers. The European trend of strong loyalty to local brands is increasingly manifesting within Ukrainian consumer behaviour. It is important to emphasise that the implementation of this principle is being advanced not only by the private sector but also by the state. On October 11, 2024, the National Cashback Program, initiated by the President of Ukraine, was officially launched (Ministry of

Economy of Ukraine, 2024). This initiative aims to support both Ukrainian consumers and domestic producers. Under the program, consumers receive a 10% refund on purchases of Ukrainian-made products, while producers benefit from increased demand stimulated by government incentives.

The expected growth in consumer demand for goods of Ukrainian origin has the potential to expand domestic production, reduce dependence on imports and reorient the market towards national producers. This will support business activity, preserve employment and strengthen the economic stability of small and medium-sized enterprises, creating the conditions for the gradual recovery of the economy. Additionally, developing local supply chains and increasing the role of the domestic market can be important factors of economic stabilisation in the post-war period. However, the potential of these processes is limited by falling real incomes, a decline in effective demand and concentration of household spending on essential goods. This may reduce the possibilities of fully implementing consumer support for the national producer. Therefore, the formation of systemic instruments of economic regulation aimed at harmonising the effective demand of the population with the potential of domestic production becomes particularly relevant.

CONCLUSIONS

The full-scale war in Ukraine has led to a drop in incomes, inflation, and rising unemployment. All this has had a significant impact on the purchasing power of the population. The security factor also increased – Ukrainians are changing their habits, avoiding crowds, choosing online shopping more often and focusing on the most necessary products. The deterioration in customer safety led to a shift in consumer priorities and a redistribution of spending. Established gastronomic practices of Ukrainians have been disrupted, and daily eating patterns and diets have changed. The war changed the categories of goods that Ukrainians buy most often. Demand has shifted toward staples (eggs, bread, pasta, cereals, dairy products), long-term storage products, and cheaper alternatives. At the same time, consumption of vegetables, fruits, fish, and beverages decreased, in part due to rising prices. The Consumer Price Index for food products increased in 2023-2024, forcing people to reconsider their habits and cut back on spending. Nearly two-third of them chose cheaper products than they had before.

The war caused severe psychological stress. Eating disorders, panic purchases, and impulsive stockpiling were typical reactions of Ukrainians in the first weeks of the full-scale invasion. Over time, the behaviour evolved: there was a tendency to rationalise spending, restore "emotional comfort" through the consumption of favourite foods or brands that inspire trust and are associated with pre-war life. Ukrainians have become more active in supporting domestic producers. Consumer loyalty to Ukrainian brands, especially those that support the Armed Forces or socially vulnerable groups, has increased significantly. The volume of purchases through online platforms also increased, particularly among the elderly and internally displaced persons. During 2022-2025, the proportion of older adults shopping for groceries online grew the most rapidly. The share of online shoppers among those aged 58 and older increased by more than twofold, while for young people under 28, the increase was 27%. By 2025, IDPs' online food spending had almost equalled that of people who did not change their residence place during the war. This suggested that IDPs have adapted to their new circumstances, with a certain degree of convergence in consumer behaviour between these two groups. Thus, ecommerce became not only a means of saving money, but also a safe way to meet consumers' basic needs. Given this, future research should focus on examining the business model transformation practices of Ukrainian retailers in order to respond more effectively to changes in consumer behaviour amid the ongoing war.

ACKNOWLEDGEMENTS

The authors express their sincere gratitude to all colleagues and experts who provided valuable insights and feedback during the preparation of this work.

FUNDING

None.

CONFLICT OF INTEREST

None.

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Вплив війни на споживчу поведінку та купівельні патерни на продовольчому ринку України

Анотація. Метою дослідження був аналіз зміни споживчої поведінки покупців продовольчих товарів внаслідок російсько-української війни та виявлення головних чинників цієї зміни. В дослідженні використано комплекс загальнонаукових методів, зокрема спостереження, аналіз і синтез, узагальнення, порівняння та індукцію. Результати засвідчили, що попри трансформацію системи продовольчого забезпечення України в умовах війни, споживча активність залишалася відносно стабільною, що зумовлено стійкістю та адаптивністю вітчизняного аграрного сектору до викликів воєнного часу. Установлено, що основними чинниками, які визначають споживчі рішення в умовах кризи, є економічна нестабільність, безпекові ризики та психологічні фактори. У воєнний період зазначені чинники набули нових форм прояву та посилюють свій вплив на поведінку споживачів. З'ясовано, що вплив пандемії COVID-19 та війни в Україні має кумулятивний ефект негативних потрясінь. Відзначено зростання популярності онлайн-покупок продовольчих товарів та залучення до цифрової комерції нових груп споживачів. Проаналізовано динаміку купівельної активності українців в сегменті продуктів харчування. Досліджено та описано тенденції розповсюдженості онлайн-покупок продовольчих товарів в розрізі основних соціально-демографічних характеристик споживачів. Доведено, що погіршення безпекової ситуації спричинило переоцінку споживчих пріоритетів і перерозподіл витрат домогосподарств. Водночас традиційні харчові звички зазнали змін, що позначилося на структурі раціону та повсякденних моделях харчування населення. Описано особливості харчування різних груп населення України на початку повномасштабного вторгнення та психологічні чинники впливу на споживчу поведінку. Досліджено феномен панічних покупок під час криз та посилення орієнтації споживачів на українські бренди, особливо ті, що підтримують Збройні Сили України та соціально уразливі категорії населення

Ключові слова: ринок харчових продуктів; війна в Україні; панічні покупки; раціоналізація споживання; продовольча безпека; кризові умови

ECONOMICS OF DEVELOPMENT
Journal homepage: https://ecdev.com.ua/
ISSN: 1683-1942
E-ISSN: 2304-6155
Vol. 25, No. 3, 2026
UDC 656.615:330.322:004
DOI: 10.63341/econ/3.2026.46

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Digital competencies and human capital for sustainable economic development

Abstract. The purpose of this study was to investigate how digital competencies and digital human capital contribute to sustainable economic development by influencing productivity, competitiveness, innovation capacity, labour-market transformation, and long-term economic resilience. The materials consisted of open data and analytical reports published by European and international institutions, including sources on digital skills, artificial intelligence adoption, labour-market transformation, and digital development. The methodological basis of the study included comparative analysis, synthesis of institutional and statistical data, structural analysis of labour-market trends, calculation of digital-skills gaps and normalised indicators, scenario analysis, and a strengths, weaknesses, opportunities, and threats matrix. The results showed that digital competencies affect sustainable development through productivity growth, innovation capacity, economic inclusion, labour-market adaptability, and institutional resilience. Particular attention was devoted to evaluating Ukraine's digital transformation in comparison with the European Union and to identifying strategic policy priorities capable of strengthening digital human capital in the context of European integration and post-war economic recovery. The comparative analysis indicated that Ukraine is close to the European Union average in basic digital skills but still faces significant risks related to uneven access, migration of skilled workers, insufficient artificial intelligence literacy, and outdated educational programmes. The extended quantitative assessment showed that, if the 2021-2025 trend continues, Ukraine may reach only about 64.4 percent of adults with at least basic digital skills by 2030, remaining 15.6 percentage points below the recommended benchmark. The article argued that Ukraine's digital human-capital strategy should combine lifelong learning, data literacy, artificial intelligence literacy, science, technology, engineering, and mathematics education, digital inclusion, and smart regional policy. The practical value of the study lies in the proposed framework for connecting digital competencies with productivity, competitiveness, and recovery policy

Keywords: workforce reskilling; artificial intelligence literacy; data literacy; digital inclusion; smart economy; productivity growth

INTRODUCTION

The contemporary economy is undergoing a structural transformation in which knowledge, data, artificial intelligence, digital platforms, and the ability of people to use them productively determine the quality of economic growth. In the industrial model, human capital was usually interpreted through education, qualifications, health, and professional experience. In the digital economy, this interpretation remains valid but becomes insufficient. A worker, entrepreneur, manager, teacher, or public servant now needs not only professional knowledge but also the capacity to operate in data-rich, platform-based, algorithmically mediated environments. Therefore, digital competencies are no longer a narrow technical category; they are becoming a general economic capability that shapes productivity, employability, innovation, and social inclusion. The relevance of this problem is strengthened by the rapid diffusion of artificial intelligence and automation. In accordance with the World Economic Forum (2025), employers expect substantial changes in core skills between 2025 and 2030, while analytical thinking, technological

Article's History: Received: 23.04.2026; Revised: 27.07.2026; Accepted: 01.09.2026; Published: 02.10.2026

Suggested Citation:

Yarema, O. (2026). Digital competencies and human capital for sustainable economic development. *Economics of Development*, 25(3), 46-57. doi: 10.63341/econ/3.2026.46.

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literacy, resilience, flexibility, and lifelong learning remain central for future employment. The Stanford artificial intelligence index also shows that the use of artificial intelligence in organisations accelerated from 55 percent in 2023 to 78 percent in 2024, while private investment in generative artificial intelligence reached USD 33.9 billion in 2024 (Maslej *et al*., 2025).

These trends indicate that digital competencies are becoming a necessary condition for converting technology into economic value. The International Labour Organization (2024) likewise emphasised that digital transformation is reshaping labour markets by increasing demand for digital competencies, lifelong learning, and workforce adaptability across economic sectors. For Ukraine, this issue is especially important because digital transformation coincides with war-related economic losses, labour migration, demographic pressure, infrastructure damage, and the need for post-war modernisation. Digital public services, information-technology exports, educational platforms, and the adaptability of citizens form a strong foundation for recovery. At the same time, uneven access to digital infrastructure, differences between age groups and regions, migration of skilled workers, and limited artificial intelligence literacy create serious constraints. From an economic perspective, insufficient digital competencies create measurable constraints on productivity growth and business competitiveness. Enterprises lacking a digitally skilled workforce experience slower technology adoption, lower innovation performance, reduced capacity to integrate into digital value chains, and weaker resilience to external shocks. These challenges are particularly relevant for small and medium-sized enterprises, which account for a substantial share of employment and regional economic activity but often face limited financial and organisational capacity for digital transformation. Consequently, strengthening digital competencies should be regarded as an investment in productive human capital capable of increasing labour efficiency, stimulating innovation, improving firms' competitiveness, and accelerating Ukraine's post-war economic recovery.

The reviewed studies demonstrated broad agreement that digital competencies have become a fundamental component of human capital in the digital economy. However, important differences remain regarding the mechanisms through which these competencies contribute to sustainable economic development. P. Verhoef *et al*. (2021) demonstrated that digital transformation is an organisation-wide process in which technological change interacts with organisational structures, capabilities, and business-model transformation, indicating that technology alone is insufficient to generate sustainable economic value. Similarly, B. Đorđević *et al*. (2025) demonstrated that digital competencies substantially improve employability and labour-market adaptability, while R. Cramarenco *et al*. (2023) concluded that the economic benefits of artificial intelligence depend primarily on complementary human skills rather than technology alone. These findings reinforce the argument that investments in digital competencies should be interpreted as investments in long-term economic growth rather than purely educational initiatives. S. Qureshi (2023) argued that unequal access to digital competencies may deepen economic and social disparities. Recent empirical evidence further confirms that the economic benefits of digital transformation depend on the quality of human capital and the development of complementary digital competencies.

This broader interpretation is also supported by A. Abina *et al*. (2022), who demonstrated that sustainability-related competencies increasingly require the integration of digital, analytical, and interdisciplinary skills to support informed decision-making and long-term sustainable development. G. Vial (2019) additionally argued that digital transformation should be interpreted as a comprehensive organisational process that reshapes value creation mechanisms, organisational structures, and competitive advantages rather than representing merely technological change. The impact of artificial intelligence on human capital has received particular attention in recent research. McKinsey Global Institute (2023) argued that generative artificial intelligence can contribute to productivity growth, but its economic effect depends on the ability of organisations and workers to redesign business processes and use new tools effectively. A. Green (2024) reached a similar conclusion, emphasising that artificial intelligence increasingly complements rather than replaces human labour by raising demand for analytical, communication, and problem-solving skills across modern labour markets. The issue of digital skills is also closely connected with labour-market transformation.

European policy documents provide an important benchmark for evaluating digital competencies. The European Commission (2024) defined digital skills as one of the central targets of the Digital Decade, setting the goal that at least 80 percent of adults should have at least basic digital skills by 2030. Eurostat (2026) data showed that the European Union is gradually approaching this target, although the gap remains significant. For Ukraine, this benchmark is relevant in the context of European integration, post-war recovery, and the need to modernise education, labour-market policy, and regional development. For Ukraine, the literature and policy reports indicate both opportunities and risks. On the one hand, the country has strong digital public services, a developed information-technology sector, digital education platforms, and a high level of adaptability among citizens. On the other hand, the development of digital human capital is constrained by migration of skilled workers, regional inequality, uneven access to digital infrastructure, and insufficient artificial intelligence literacy outside the technology sector. Therefore, further research should focus on how digital competencies can be transformed into productivity growth, innovation capacity, and inclusive sustainable development.

Another important stream of contemporary research demonstrates that artificial intelligence complements rather than simply substitutes human labour. E. Mäkelä *et al*. (2024), based on online vacancy data, showed that artificial intelligence increases demand for complementary skills such as digital literacy, teamwork, and resilience. This result is important for sustainable development because it suggests that economies should not focus exclusively on narrow technical training. Existing studies primarily analyse digital competencies from educational, technological, or labour-market perspectives, whereas considerably less

attention has been devoted to explaining the economic mechanisms through which digital competencies influence productivity growth, enterprise competitiveness, innovation capacity, and sustainable economic development. Furthermore, relatively few studies integrate these relationships within the specific context of Ukraine's post-war economic recovery and European integration. Addressing these research gaps constitutes the main objective of the present study. The purpose of this study was to explain the economic mechanisms through which digital competencies, as a strategic component of human capital, contribute to sustainable economic development by improving labour productivity, strengthening enterprise competitiveness, enhancing innovation capacity, and supporting resilient labour-market transformation in Ukraine.

MATERIALS AND METHODS

The study was designed as an analytical article based on secondary data, institutional reports, and author's quantitative calculations. The research was conducted according to a sequential analytical framework consisting of five consecutive stages. During the first stage, current scientific literature and institutional documents were analysed to identify theoretical approaches explaining the relationship between digital competencies, human capital, and sustainable economic development. The second stage involved collecting and systematising statistical indicators describing digital skills in Ukraine and the European Union. During the third stage, comparative calculations and analytical indicators were performed to assess the scale of the digital-skills gap and its dynamics. The fourth stage included scenario analysis and SWOT analysis to evaluate the potential trajectories of Ukraine's digital human-capital development. Finally, the obtained results were interpreted from the perspective of their economic implications for productivity, competitiveness, labour-market resilience, and sustainable development.

The empirical basis of the study included open statistical and analytical materials published by international and national institutions, primarily covering the period from 2021 to 2025. Sources were selected according to three criteria: relevance to digital competencies, human capital, labour-market transformation, or artificial intelligence adoption; methodological transparency and institutional reliability; and availability of comparable quantitative indicators or analytical evidence applicable to Ukraine and the European Union. The European Union benchmark was formed using Eurostat (2026) data on the share of individuals aged 16-74 with at least basic digital skills, including the 2021 and 2025 values used to assess changes over time, together with the European Commission's (2024) Digital Decade target of at least 80 percent of adults possessing basic digital skills by 2030. For Ukraine, Diia.Education (2025) data were used to identify the share of the population with at least basic digital skills in 2025, while earlier Ukrainian digital-skills data (East Europe Foundation, 2021) were used to assess changes over time. These indicators were subsequently used to calculate the gap from the 2030 benchmark, the normalised digital-skills index, average annual change, required annual progress, and trend-based projections. Labour-market and technology-transformation trends were examined using reports of the McKinsey Global Institute (2023), the Organisation for Economic Co-operation and Development (OECD, 2024), the World Bank Group (2024), World Economic Forum (2025), and the Stanford Artificial Intelligence Index (Maslej *et al*., 2025).

The methodological approach combined several complementary research methods. Comparative analysis was applied to compare Ukraine and the European Union using selected digital-skills indicators. The comparison was based on five criteria: the share of the population with at least basic digital skills in 2025, the strategic benchmark for 2030, the gap from the 2030 benchmark, the normalised digital-skills index with the benchmark set at 100, and the observed change in basic digital skills over 2021-2025. These criteria were selected because they jointly capture the current level of digital-skills development, the distance from the strategic target, the relative degree of target achievement, and the dynamics of progress over time, thereby allowing the positions of Ukraine and the European Union to be assessed within a common analytical framework. Structural analysis was employed to distinguish six groups of digital competencies: basic digital skills, data literacy, artificial intelligence literacy, cybersecurity skills, platform competencies, and lifelong-learning capacity, and to assess their contribution to productivity, competitiveness, and social inclusion. Synthesis and generalisation integrated findings from academic literature and international policy reports into a coherent analytical framework. Simple statistical processing was used to calculate percentage-point changes, gaps from strategic targets, and normalised digital-skills indices. Scenario analysis supported the assessment of alternative trajectories for digital-competency development in Ukraine until 2030. Finally, SWOT analysis was applied to identify and systematised the principal internal and external factors influencing Ukraine's digital human capital and its contribution to sustainable economic development. Strengths and weaknesses were classified as internal factors reflecting the existing characteristics of Ukraine's digital human capital, including the level and structure of digital competencies, human-capital capacity, educational potential, and existing structural disparities. Opportunities and threats were classified as external factors arising from the technological, economic, institutional, and geopolitical environment, including artificial intelligence diffusion, European integration, investment and reconstruction processes, technological change, migration, and regional inequality.

The calculation procedure was intentionally transparent and reproducible. The digital-skills gap was calculated as the difference between the 2030 benchmark of 80 percent and the observed share of the population with at least basic digital skills. The normalised digital-skills index was calculated as the ratio of the observed value to the benchmark value, multiplied by 100. The absolute change was calculated in percentage points. For the European Union, the change is calculated between 2021 and 2025, using Eurostat (2026) data. For Ukraine, the comparison is based on available benchmark values reported by Ukrainian digital-skills research (East Europe Foundation, 2021) and the data published by Diia.Education (2025). These calculations did not claim to be a full econometric model; their purpose was to provide an analytical basis for interpreting the scale of the digital-skills challenge. The methodological approach ensured analytical consistency

by combining quantitative indicator assessment with qualitative policy interpretation. Although the study was not based on econometric modelling, the integrated use of comparative analysis, scenario modelling, and strategic assessment provides sufficient analytical depth for identifying the principal economic mechanisms connecting digital competencies with sustainable economic development. The limitation of the study was that available digital-skills indicators were not fully harmonised across countries and years. European Union data were based on Eurostat (2026) methodology, while Ukrainian data were derived from national research. Therefore, the comparison should be interpreted as indicative rather than strictly identical in survey design. Another limitation is that digital competencies are multidimensional and cannot be fully represented by a single basic-skills indicator. To compensate for this limitation, the article also analyses qualitative dimensions: data literacy, artificial intelligence literacy, cybersecurity skills, platform competencies, and lifelong-learning capacity.

RESULTS AND DISCUSSION

Economic mechanisms of the influence of digital competencies on sustainable development

Digital competencies influence sustainable economic development through several interconnected channels. The first channel is productivity. Workers who can use digital tools, data systems, and artificial intelligence applications perform routine operations faster, make more informed decisions, and participate more effectively in digital production processes. The second channel is innovation. Digital competencies enable firms to create new products, use platform-based business models, process large datasets, and integrate into global digital value chains. This interpretation is consistent with S. Nambisan *et al*. (2017), who argued that digital innovation transforms value creation by enabling new forms of collaboration, digital platforms, and innovation ecosystems that strengthen firms' innovation capacity. The third channel is inclusion. When citizens possess basic digital skills, they can access electronic public services, online education, remote work, digital finance, and entrepreneurial opportunities. The fourth channel is resilience. Economies with digitally competent citizens and firms adapt faster to shocks, because production, education, public administration, and services can partly move online.

The economic meaning of digital competencies is therefore broader than the ability to use a computer or smartphone. In a sustainable-development context, digital competencies should be interpreted as a layered system. The basic layer includes functional digital literacy, safe use of devices, communication through digital channels, and access to online services. The intermediate layer includes the ability to work with spreadsheets, databases, cloud platforms, electronic commerce, digital marketing, and online collaboration. The advanced layer includes data literacy, artificial intelligence literacy, cybersecurity, programming, process automation, and the ability to evaluate algorithmic outputs critically. Sustainable development requires all three layers because advanced digital sectors cannot grow without basic inclusion, while basic inclusion alone does not create high productivity. The principal economic mechanisms through which digital competencies influence sustainable economic development are summarised in Table 1.

Table 1. Economic mechanisms of digital competencies in sustainable development

Competency group	Economic mechanism	Expected development effect
Basic digital literacy	Access to electronic services, online education, digital finance, and digital communication	Lower transaction costs, greater inclusion, wider participation in the formal economy
Data literacy	Use of data in business decisions, public management, forecasting, and monitoring	Improved quality of decisions, better resource allocation, evidence-based policy
Artificial intelligence literacy	Ability to use, evaluate, and supervise artificial intelligence tools in professional tasks	Automation of routine processes, productivity growth, new hybrid occupations
Science, technology, engineering, and mathematics competencies	Preparation of specialists for high-technology sectors and innovation ecosystems	Expansion of technological entrepreneurship and research-based innovation
Cybersecurity skills	Protection of digital infrastructure, data, and institutional trust	Lower digital risks and higher resilience of public and private systems
Lifelong-learning capacity	Continuous renewal of professional skills during technological change	Reduced structural unemployment and improved labour-market adaptability

Source: author's systematisation based on European Commission (2024), OECD (2024), World Bank Group (2024) and World Economic Forum (2025)

Table 1 demonstrates that digital competencies generate economic effects through several interrelated mechanisms rather than through a single channel. Basic digital literacy reduces transaction costs and expands access to formal economic activity, while data literacy improves the quality of managerial and policy decisions. This interpretation is further supported by F. Stephany & O. Teutloff (2024), who demonstrate that the economic value of digital skills increasingly depends on their complementarity with artificial intelligence technologies rather than on isolated technical abilities. M. Janssen *et al*. (2017) similarly demonstrate that the quality of strategic and public-sector decision-making increasingly depends on the effective use of large-scale digital data and evidence-based management approaches. Artificial intelligence literacy is particularly important for productivity growth because it enables workers and firms to automate routine tasks, improve forecasting, and redesign business processes. Cybersecurity skills increase institutional and business resilience by reducing risks associated with digital infrastructure. Therefore, the economic value of digital competencies lies in their cumulative effect on productivity, innovation, competitiveness, inclusion, and the stability of economic systems.

The proposed classification of economic mechanisms is generally consistent with recent international research while extending it through a stronger macroeconomic

perspective. P. Verhoef *et al*. (2021) mainly associated digital transformation with changes in business models and firm-level competitiveness, whereas D. Kee *et al*. (2023) emphasised improvements in employability and workforce adaptability. R. Cramarenco *et al*. (2023) focused on the complementarity between artificial intelligence and human capabilities, while E. Mäkelä *et al*. (2024) demonstrated that artificial intelligence increases demand for complementary rather than substitute skills. The present study extends previous research by integrating these perspectives into a unified economic framework explaining how digital competencies simultaneously increase labour productivity, enterprise competitiveness, innovation capacity, institutional resilience, and long-term sustainable economic development. K. Warner & M. Wäger (2019) similarly demonstrated that successful digital transformation depends on the continuous development of dynamic organisational capabilities enabling strategic renewal under rapidly changing technological conditions. Digital human capital should be interpreted not only as an educational resource but also as a strategic factor of long-term economic growth.

Comparative assessment of digital skills in Ukraine and the European Union: Progress towards the 2030 benchmark

The comparative data confirm that basic digital skills remain a central challenge even in developed economies. The European Union improved its indicator from 54 percent in 2021 to 60 percent in 2025, but this still leaves a 20 percentage-point gap from the 2030 target. Ukraine's 2025 value of 57.5 percent is close to the European Union average, which demonstrates the strength of Ukraine's digital adaptation. However, the remaining gap from the 80 percent target is 22.5 percentage points. This means that a gradual and fragmented approach will be insufficient; Ukraine needs a mass digital-skills policy that reaches adults, older citizens, internally displaced persons, rural communities, teachers, small entrepreneurs, public servants, and workers in traditional sectors.

The normalised index also illustrates the policy challenge. If the 2030 target is taken as 100, the European Union reached 75.0 percent of the target in 2025, while Ukraine reached 71.9 percent. The difference is not dramatic, but it is economically significant because digital-skills gaps accumulate through labour-market inequality, differences in productivity, and unequal access to new technologies. Moreover, basic digital skills are only the first step. The transition from basic skills to data literacy and artificial intelligence literacy is more difficult because it requires not only access to devices but also updated educational content, competent teachers, practice-oriented training, and trust in digital systems. A comparative assessment of digital-skills indicators for Ukraine and the European Union is presented in Table 2.

Table 2. Selected digital-skills indicators and author's calculations

Indicator	European Union	Ukraine	Analytical interpretation
Population with at least basic digital skills in 2025	60.0 percent	57.5 percent	Ukraine is close to the European Union average, but both indicators remain below the strategic benchmark
Strategic benchmark for 2030	80.0 percent	80.0 percent as a recommended policy benchmark	The benchmark can be used as a reference point for Ukrainian digital policy
Gap from the 2030 benchmark	20.0 percentage points	22.5 percentage points	Ukraine's gap is 2.5 percentage points larger than the European Union gap
Normalised digital-skills index, benchmark equals 100	75.0	71.9	Ukraine has reached about 72 percent of the recommended benchmark
European Union change from 2021 to 2025	plus 6.0 percentage points	not fully comparable because of different survey waves	The European Union trend shows that progress is gradual and requires systematic policy

Source: author's calculations based on European Commission (2024), Diia.Education (2025), Eurostat (2026)

The indicators presented in Table 2 have direct economic implications. Ukraine's proximity to the European Union average in basic digital skills indicates that the country has a relatively strong foundation for digital transformation. However, the remaining 22.5 percentage-point gap from the 2030 benchmark shows that this foundation is still insufficient for achieving broad-based productivity gains. If digital competencies remain unevenly distributed across regions, age groups, enterprises, and sectors, the economic benefits of digitalisation will be concentrated mainly in the information-technology sector and large urban centres. This may weaken the capacity of small and medium-sized enterprises, traditional industries, and regional economies to participate in digital value creation. To deepen the analytical component of the study, the comparative indicators were supplemented by calculations of actual annual progress, required annual progress to reach the 2030 benchmark, and a simple trend-based projection. This approach makes it possible to assess not only the current gap but also the speed of change required for Ukraine and the European Union to achieve the strategic target of 80 percent of adults with at least basic digital skills. The extended quantitative calculations describing progress towards the Digital Decade benchmark are presented in Table 3.

Table 3. Extended quantitative assessment of progress toward the 2030 digital-skills benchmark

Indicator	European Union	Ukraine	Analytical interpretation
Observed change in basic digital skills, 2021-2025	+6.0 percentage points	+5.5 percentage points	Both trajectories are positive, but the pace remains insufficient for the 2030 target
Average annual change, 2021-2025	+1.50 percentage points per year	+1.38 percentage points per year	Ukraine's annual improvement is close to the European Union trend, but slightly lower

Table 3. Continued

Indicator	European Union	Ukraine	Analytical interpretation
Required annual change, 2025-2030	+4.00 percentage points per year	+4.50 percentage points per year	Ukraine needs a faster acceleration to close the larger remaining gap
Acceleration coefficient needed to reach the 2030 benchmark	2.67 times compared with the 2021-2025 pace	3.27 times compared with the 2021-2025 pace	The Ukrainian trajectory requires more than a threefold acceleration of digital-skills diffusion
Projected 2030 value if the 2021-2025 trend continues	67.5 percent	64.4 percent	Continuation of the current trend would not be sufficient to achieve the benchmark
Remaining shortfall under the trend scenario	12.5 percentage points	15.6 percentage points	The forecast confirms the need for active policy interventions rather than passive diffusion

Source: author's calculations based on East Europe Foundation (2021), European Commission (2024), Diia.Education (2025), Eurostat (2026)

The extended calculations show that the key issue is not only the existence of a digital-skills gap but also the insufficient speed of convergence toward the 2030 benchmark. At the 2021-2025 pace, the European Union would reach only 67.5 percent by 2030, while Ukraine would reach approximately 64.4 percent. Therefore, Ukraine would remain 15.6 percentage points below the recommended benchmark. This result supports the argument that passive diffusion of digital skills is not enough. A stronger policy mix is required, including adult reskilling, artificial intelligence literacy, digital inclusion programmes, regional competence centres, and closer cooperation between universities, business, and public administration. From an economic-policy perspective, these calculations show that Ukraine cannot rely solely on spontaneous market adaptation. The required acceleration of digital-skills diffusion implies the need for coordinated public and private investment in human capital. Without such acceleration, the digital-skills gap may limit productivity growth, reduce the competitiveness of enterprises, slow down the adoption of artificial intelligence, and deepen regional and sectoral inequality. This is especially important for small and medium-sized enterprises, which often lack sufficient financial and organisational resources for systematic digital upskilling but play a crucial role in employment, local economic development, and post-war recovery.

Figure 1 demonstrates that the European Union has a steady but moderate upward trend. Ukraine's available indicator is close to the European trajectory, which supports the argument that Ukraine has a meaningful digital foundation. This conclusion is also consistent with the United Nations Development Programme (2024), which identifies digital transformation as one of the key instruments supporting Ukraine's institutional resilience, economic recovery, and modernisation. However, the distance to the 2030 benchmark remains large. A purely natural diffusion of digital skills is unlikely to be enough. Digital competencies must be integrated into formal education, vocational training, adult education, public-sector modernisation, and business-support programmes.

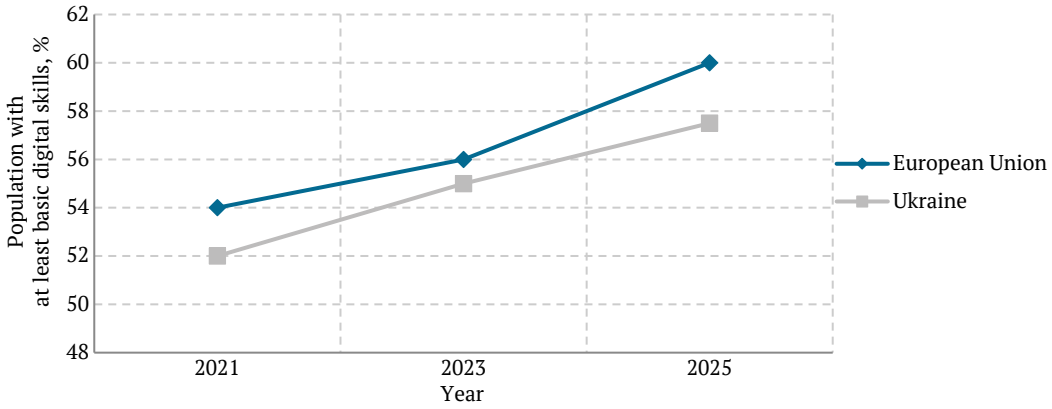


Figure 1. Dynamics of basic digital skills in the European Union and Ukraine
Source: developed by the author based on East Europe Foundation (2021), Diia.Education (2025), Eurostat (2026)

Artificial intelligence changes the structure of the digital-skills problem. Basic skills allow citizens to participate in digital society, but artificial intelligence literacy determines whether workers and firms can benefit from the next wave of technological change. The Stanford data on business adoption show that artificial intelligence is already moving from experimental use to organisational practice (Maslej *et al*., 2025). At the same time, McKinsey Global Institute (2023) emphasised that the productivity effect of generative artificial intelligence depends on the redesign of work processes and on the ability of people to use these tools. This creates a new form of inequality: not only between those who have and do not have internet access, but between those who can and cannot use intelligent systems productively and critically.

This interpretation is consistent with recent studies showing that digital skills affect not only employability but also the capacity of workers and firms to adapt to structural technological change. D. Kee *et al*. (2023) demonstrated that digital-skills acquisition improves

perceived employability, while B. Đorđević *et al*. (2025) confirmed the positive relationship between digital skills and labour-market outcomes. However, the findings of the present study extend this argument by showing that the challenge for Ukraine is not limited to employability. Digital competencies should also be considered a prerequisite for enterprise modernisation, innovation diffusion, regional competitiveness, and sustainable economic recovery. These findings indicate that the economic significance of digital competencies becomes even more pronounced when artificial intelligence literacy is considered an integral component of digital human capital capable of generating long-term macroeconomic benefits.

Artificial intelligence literacy and digital human capital as drivers of Ukraine's economic development

For Ukraine, artificial intelligence literacy should be regarded as a strategic component of digital human capital and one of the key drivers of long-term economic development. Its economic significance extends beyond technological modernisation because artificial intelligence directly influences labour productivity, gross value added, exports of knowledge-intensive services, employment transformation, investment attractiveness, and the competitiveness of the national economy. For instance:

1) Expansion of exports of knowledge-intensive services. Artificial intelligence strengthens the international competitiveness of Ukraine's information-technology sector and other knowledge-intensive industries. Increasing the number of highly qualified digital specialists enables enterprises to expand exports of high-value digital services, integrate into global value chains, and improve the country's external economic performance.

2) Labour productivity and gross value added. Artificial intelligence contributes to higher productivity by automating routine operations, improving forecasting accuracy, optimising production processes, and supporting managerial decision-making. As a result, enterprises generate greater gross value added while using labour, financial, and technological resources more efficiently.

3) Employment transformation. Rather than simply replacing workers, artificial intelligence changes the structure of labour demand by increasing the need for specialists possessing complementary digital competencies, analytical thinking, creativity, and interdisciplinary skills. Consequently, investments in digital human capital improve labour-market adaptability, reduce structural unemployment risks, and strengthen workforce resilience.

4) Investment attractiveness. The availability of highly qualified digital human capital significantly increases Ukraine's attractiveness for foreign direct investment. International investors increasingly evaluate not only physical infrastructure but also the capacity of enterprises and institutions to implement advanced digital technologies, making artificial intelligence literacy an important determinant of technological modernisation.

5) Post-war economic recovery. Artificial intelligence literacy should also be considered a strategic instrument for rebuilding Ukraine's economy. Intelligent technologies support infrastructure reconstruction, logistics optimisation, transparent public administration, efficient allocation of financial resources, modernisation of enterprises, and evidence-based policy decisions. Therefore, investments in artificial intelligence competencies contribute simultaneously to higher productivity, stronger competitiveness, sustainable economic growth, and greater resilience of the national economy.

However, the economic effect of artificial intelligence is not automatic. The literature on skill complementarity suggests that artificial intelligence increases the value of certain human capabilities, especially analytical thinking, digital literacy, communication, teamwork, and resilience (Mäkelä *et al*., 2024). This is consistent with the World Economic Forum's (2025) emphasis on analytical thinking, creative thinking, technological literacy, and resilience as key future skills. Therefore, Ukrainian educational policy should avoid the narrow interpretation of artificial intelligence literacy as only programming or prompt writing.

M. Laupichler *et al*. (2022) argued that artificial intelligence literacy should be understood as a multidimensional competence combining technical understanding, ethical awareness, critical evaluation of AI systems, and responsible decision-making across professional contexts. It should include understanding of data, limitations of models, verification of outputs, ethics, cybersecurity, privacy, and domain-specific application. Similarly, D. Ng *et al*. (2021) conceptualised AI literacy as an interdisciplinary competence integrating technological knowledge, human-centred thinking, ethical reasoning, and practical problem-solving required for effective interaction with intelligent systems. D. Long & B. Magerko (2020) further identified AI literacy as a set of competencies that includes understanding AI capabilities and limitations, interpreting AI-generated outputs critically, recognising ethical implications, and making informed decisions regarding the use of intelligent technologies. The strategic strengths, weaknesses, opportunities, and threats associated with Ukraine's digital human capital are summarised in Table 4.

Table 4. Strengths, weaknesses, opportunities, and threats of Ukraine's digital human capital

Strengths	Weaknesses	Opportunities	Threats
Strong information-technology sector supporting exports of high-value digital services and integration into global value chains	Migration of highly qualified specialists leading to human-capital losses, lower innovation capacity, and slower productivity growth	Integration into the European Digital Single Market, creating opportunities for expanding exports of knowledge-intensive services and attracting investment	Global competition for digital talent increasing the risk of permanent brain drain and declining innovation potential
Developed digital public services reducing transaction costs for citizens and businesses and improving institutional efficiency	Digital divide across regions, age groups, and income levels limiting labour-market participation and access to digital public services	Post-war reconstruction based on digital technologies capable of increasing productivity and modernising infrastructure	Growing inequality between digitally included and excluded population groups, reducing social cohesion and labour-market efficiency

Table 4. Continued

Strengths	Weaknesses	Opportunities	Threats
Expanding digital education ecosystem supporting workforce reskilling and lifelong learning	Insufficient artificial-intelligence and data-literacy skills outside the IT sector slowing technology adoption in traditional industries	Expansion of lifelong learning programmes improving workforce adaptability and enterprise competitiveness	Dependence on foreign digital platforms and technologies limiting technological sovereignty and long-term competitiveness
High entrepreneurial and innovation potential facilitating digital business creation and commercialisation of new technologies	Outdated educational programmes reducing the supply of specialists with competencies demanded by the digital economy	Development of smart regional ecosystems stimulating innovation, SME development, and regional competitiveness	Cybersecurity threats increasing economic losses, business risks, and vulnerability of critical infrastructure
European integration supporting institutional modernisation and harmonisation with EU digital standards	Unequal access to broadband infrastructure constraining digital inclusion and economic participation in rural areas	Attraction of remote work, digital entrepreneurship, return migration, and foreign direct investment	Automation of routine occupations increasing structural unemployment risks without effective reskilling policies

Source: author's development based on the results of the study

The SWOT analysis presented in Table 4 reveals a structural imbalance in Ukraine's digital human capital: a strong information-technology sector, advanced digital public services, and entrepreneurial capacity create significant potential for productivity growth and technological modernisation, while skilled-labour migration, unequal access to digital opportunities, and insufficient artificial-intelligence literacy constrain its realisation. Consequently, converting Ukraine's existing digital strengths into sustainable economic gains requires coordinated investment in workforce reskilling, digital inclusion, education modernisation, and regional human-capital development. This conclusion corresponds with N.J. Foss *et al*. (2023), who emphasised that ecosystem leadership and dynamic capabilities determine the long-term ability of organisations and national economies to sustain innovation and competitive advantage during periods of technological change.

The SWOT analysis also indicates that the economic benefits of Ukraine's digital strengths depend on the diffusion of digital competencies beyond the information-technology sector. Sustainable productivity growth requires broader adoption of data, platform, cybersecurity, and artificial-intelligence competencies by small and medium-sized enterprises, public institutions, education, healthcare, transport, and agriculture. Without such diffusion, technological progress may remain concentrated in a limited number of advanced sectors rather than generate economy-wide productivity gains. Scenario analysis helps to clarify possible trajectories to 2030. The conservative scenario assumes slow curriculum renewal, limited adult learning, weak regional policy, and fragmented artificial intelligence education. Under this scenario, Ukraine may preserve current digital strengths but fail to convert them into broad productivity growth. The baseline scenario assumes systematic development of digital literacy, science, technology, engineering, and mathematics education, and moderate integration of data and artificial intelligence tools into professional training. This scenario would support competitiveness but might still leave vulnerable groups behind. The optimistic scenario assumes mass development of artificial intelligence literacy, expansion of lifelong learning, smart regional ecosystems, and stronger cooperation between universities, business, and public administration. This scenario would create the strongest conditions for sustainable digital development. The possible scenarios for the future development of digital competencies in Ukraine are presented in Table 5.

Table 5. Scenarios for digital-competency development in Ukraine to 2030

Scenario	Main assumptions	Expected economic effect	Main risks
Conservative	Slow renewal of education, fragmented adult training, limited artificial intelligence literacy	Moderate productivity growth concentrated in the existing technology sector	Expansion of digital inequality and loss of competitiveness in traditional sectors
Baseline	Development of digital literacy, science, technology, engineering, and mathematics education, and selected reskilling programmes	Improved adaptability of the labour market and gradual increase in competitiveness	Insufficient coverage of older workers, rural communities, and small enterprises
Optimistic	Mass artificial intelligence literacy, data literacy, lifelong learning, smart regional ecosystems, and cooperation between universities and business	Formation of a broad-based smart economy with stronger innovation and inclusion	Need for stable financing, institutional coordination, and cybersecurity protection

Source: author's scenario analysis

The results also show that the digital-skills agenda should be connected with sustainable development rather than treated as a separate technological policy. Sustainable development includes economic, social, and institutional dimensions. Economically, digital competencies raise productivity and support innovation. Socially, they expand access to education, work, public services, and entrepreneurship. Institutionally, they strengthen the capacity of public administration and improve evidence-based decision-making. Environmentally, digital tools may support resource efficiency, smart mobility, energy management, and monitoring of sustainable-development indicators,

although these benefits also require energy-efficient infrastructure and responsible use of technology.

Policy implications for digital human-capital development in Ukraine

The educational system is the central mechanism for long-term change. Universities should integrate digital competencies into all economic, managerial, legal, social, and humanitarian programmes, not only into computer-science programmes. For economics students, this means knowledge of data analysis, digital platforms, electronic business, financial technologies, artificial intelligence applications in forecasting, and cybersecurity risks. For managers and public servants, this means competence in digital governance, process automation, data-based decision-making, and evaluation of technological projects. For teachers, this means the ability to design digital learning environments and to develop students' critical digital thinking. At the same time, formal education cannot solve the problem alone. The pace of technological change is faster than traditional curriculum cycles.

Therefore, lifelong learning should become a permanent component of economic policy. M. Sousa & A. Rocha (2019) likewise argued that continuous digital learning has become one of the principal conditions for successful digital transformation, organisational adaptability, and sustainable competitiveness in the digital economy. Adult learning programmes must be modular, practice-oriented, accessible online and offline, and connected with real tasks. Public employment services, universities, local governments, and businesses can jointly create reskilling programmes for workers whose occupations are affected by automation. From an economic perspective, such reskilling programmes are expected to reduce structural unemployment by improving the match between workers' competencies and changing labour-market demand, shorten job-search duration, and facilitate the return of displaced or economically inactive workers to employment. By enabling workers to move towards more productive and skill-intensive occupations, these programmes may also contribute to higher individual earnings and more efficient utilisation of human capital. Special attention should be given to internally displaced persons, veterans, women returning to the labour market, older workers, and workers in small towns and rural areas. Digital inclusion is another necessary condition. If digital-skills programmes are designed only for already educated and urban populations, they will deepen inequality. Inclusion requires affordable internet access, availability of devices, accessible training formats, local digital-education centres, and support for people with disabilities.

The World Bank Group's (2024) emphasis on the digital divide is relevant here: digitalisation can either close or widen development gaps depending on whether infrastructure, skills, institutions, and productive use develop together. For Ukraine, this means that reconstruction policy should include digital infrastructure and digital-skills programmes as complementary investments. The combined development of digital infrastructure and digital competencies is expected to generate broader socio-economic effects by expanding access to employment, entrepreneurship, and financial services. Improved digital connectivity and skills can increase access to remote and platform-based employment, particularly for residents of rural areas, internally displaced persons, and other groups facing spatial or mobility constraints. For entrepreneurs and small businesses, stronger digital capabilities can lower barriers to market entry, facilitate e-commerce and access to wider markets, and improve the use of digital financial services. At the household level, digital inclusion can broaden access to online banking, payments, credit, and other financial services, thereby supporting economic participation and reducing territorial disparities in access to economic opportunities.

The business sector also plays a decisive role. Firms are the place where digital competencies are transformed into productivity. However, many enterprises, especially small and medium-sized ones, lack resources for systematic training and digital transformation. Policy instruments can include tax incentives for training, voucher programmes for digital upskilling, support for digital transformation audits, cooperation with universities, and sectoral competence centres. Such instruments would help firms move from simple use of digital communication tools to data-driven management, process automation, cybersecurity, and responsible adoption of artificial intelligence. Public administration should act both as a user and as a promoter of digital competencies. Ukraine's digital public services have already created a strong institutional foundation. The next stage should focus on data quality, interoperability, cybersecurity, and the ability of public servants to use data and artificial intelligence responsibly. Digital government is sustainable only when citizens trust digital systems and when public employees understand how to manage them. From an economic perspective, the effective use of digital technologies in public administration can reduce administrative and transaction costs, shorten the time required to deliver public services, and decrease the resources spent by businesses and citizens on interactions with government institutions. Improved data-based decision-making and process automation can also increase the efficiency of public expenditure by reducing duplication, accelerating administrative procedures, and enabling more targeted allocation of public resources. Therefore, digital ethics, privacy, transparency, and accountability must be part of competency development.

Regional policy deserves special attention because digital development is uneven. Large cities usually concentrate universities, technology companies, broadband access, and creative communities. Smaller settlements may face weaker infrastructure and fewer training opportunities. Smart regional policy should connect digital education, local business needs, innovation hubs, public services, and reconstruction projects. Regional universities can become centres of digital human-capital development by offering short programmes for local enterprises, public-sector workers, teachers, and entrepreneurs. A further issue is measurement. Ukraine needs a more detailed system for monitoring digital competencies. Basic digital-skills indicators are useful, but they do not show whether workers can use data, artificial intelligence tools, cybersecurity practices, or digital platforms in professional contexts. A national digital-competency monitoring system could include age, region, education level, occupation, sector,

and type of competence. It should also measure not only self-reported skills but practical task performance. Such monitoring would allow policymakers to identify gaps and evaluate the effectiveness of training programmes.

The discussion confirms that human capital is the mediator between technology and sustainable development. Digital infrastructure creates opportunities, but people convert these opportunities into value. Artificial intelligence may automate routine tasks, but workers must understand how to formulate tasks, verify results, integrate outputs into decisions, and manage risks. Digital platforms may open markets, but entrepreneurs need skills to use them. Public digital services may reduce transaction costs, but citizens need trust and capability to access them. Therefore, investment in digital competencies is not a social supplement to digital transformation; it is one of its core economic conditions. The results of this study are generally consistent with previous research, but they also specify the Ukrainian economic context more clearly. P. Verhoef *et al*. (2021) argued that digital transformation changes business models, organisational processes, and value creation. The findings of the present study support this conclusion by showing that digital competencies are necessary for firms to transform digital technologies into productivity and competitiveness gains. However, in Ukraine, this relationship is complicated by war-related losses, labour migration, regional inequality, and the need for post-war reconstruction.

The results also correspond with J. Zhang *et al*. (2022), who demonstrated that the digital economy and human capital can improve city sustainability. For Ukraine, this conclusion is especially relevant because regional universities, local governments, and small and medium-sized enterprises can become important actors in the development of digital human capital. Therefore, digital-skills policy should not be concentrated only at the national level or within the information-technology sector. It should also support regional competence centres, local innovation ecosystems, and sector-specific upskilling programmes. The study also complements the findings of S. Qureshi (2023), who warned that digital transformation may become a source of exclusion if human-capital development is uneven. The Ukrainian case confirms this risk. If digital competencies are concentrated among young, urban, and highly educated groups, digital transformation may deepen inequality between regions, generations, and sectors. Therefore, digital inclusion should be interpreted as an economic condition for sustainable development, because exclusion from digital skills reduces labour-market participation, limits access to entrepreneurship, and weakens the productive potential of vulnerable groups. Compared with previous studies focused primarily on employability and technological adoption, the present study highlights the broader economic role of digital competencies in strengthening enterprise competitiveness, innovation capacity, public-sector efficiency, and regional resilience. For Ukraine, the accumulated experience of rapid digital adaptation represents a potential competitive advantage, but its long-term economic value depends on converting temporary adaptability into sustainable human-capital capacity through education, workforce training, innovation policy, and inclusive access to digital opportunities. Institutionalising these mechanisms is particularly important for supporting productivity growth, economic resilience, and post-war recovery.

CONCLUSIONS

The study confirmed that digital competencies constitute a strategic economic component of human capital and represent one of the fundamental drivers of sustainable economic development under conditions of digital transformation. The findings demonstrated that investments in digital competencies generate economic benefits through higher labour productivity, stronger enterprise competitiveness, greater innovation capacity, improved labour-market adaptability, and enhanced resilience of public institutions. The comparative analysis showed that Ukraine is close to the European Union average in the share of the population with at least basic digital skills, but both Ukraine and the European Union remain below the 2030 benchmark of 80 percent. Ukraine's estimated gap from this benchmark is 22.5 percentage points, while the normalised digital-skills index shows that Ukraine has reached approximately 71.9 percent of the recommended benchmark. Additional calculations indicate that if the 2021-2025 trend continues, Ukraine may reach only about 64.4 percent by 2030 and remain 15.6 percentage points below the target. Therefore, the country requires an acceleration of digital-skills diffusion by more than three times compared with the observed 2021-2025 pace. The quantitative assessment indicated that maintaining the current pace of digital-skills development will not be sufficient for achieving the strategic objectives of the European Digital Decade. Failure to reduce the digital-skills gap may limit productivity growth, slow enterprise digitalisation, weaken innovation performance, and reduce the competitiveness of the Ukrainian economy during the post-war recovery period.

The results demonstrated that Ukraine's main strengths include a strong information-technology sector, developed digital public services, digital-education platforms, and high adaptability of citizens. The main weaknesses include migration of skilled workers, uneven access to digital infrastructure, insufficient artificial intelligence literacy and data literacy, and slow renewal of some educational programmes. The most important opportunities are connected with European integration, post-war reconstruction, smart regional development, digital entrepreneurship, and lifelong learning. The major threats are global competition for talent, automation pressure on routine occupations, cybersecurity risks, and the deepening of digital inequality. The SWOT analysis further demonstrated that Ukraine already possesses considerable digital potential, including developed digital public services, a competitive information-technology sector, and high adaptability of its population. Nevertheless, these strengths will generate sustainable economic effects only if accompanied by systematic investments in education, artificial intelligence literacy, regional digital infrastructure, lifelong learning, and stronger cooperation between universities, businesses, and public authorities.

From a policy perspective, the findings support the implementation of comprehensive digital human-capital strategies integrating education policy, labour-market policy, innovation policy, and regional development.

Particular attention should be devoted to supporting small and medium-sized enterprises, expanding adult reskilling programmes, strengthening regional competence centres, promoting artificial intelligence literacy, and reducing digital inequality among vulnerable population groups. Such measures would contribute to higher productivity, stronger competitiveness, broader innovation diffusion, and more sustainable long-term economic growth. Future research should focus on developing econometric models explaining the causal relationship between digital competencies and economic performance in Ukraine. Particular attention should be devoted to measuring the effects of digital skills on labour productivity, enterprise competitiveness, wages, innovation activity, regional economic development, and the adoption of artificial intelligence across different sectors of the economy. Such studies would provide stronger empirical evidence for designing effective digital human-capital policies and evaluating their contribution to sustainable economic development.

ACKNOWLEDGEMENTS
None.

FUNDING
None.

CONFLICT OF INTEREST
None.

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Цифрові компетентності та людський капітал для сталого економічного розвитку

Анотація. Метою цього дослідження було визначити, як цифрові компетентності та цифровий людський капітал сприяють сталому економічному розвитку через вплив на продуктивність, конкурентоспроможність, інноваційний потенціал, трансформацію ринку праці та довгострокову економічну стійкість. Матеріалами дослідження слугували відкриті дані й аналітичні звіти, опубліковані європейськими та міжнародними інституціями, зокрема джерела, присвячені цифровим навичкам, упровадженню штучного інтелекту, трансформації ринку праці та цифровому розвитку. Методологічна основа дослідження включала порівняльний аналіз, синтез інституційних і статистичних даних, структурний аналіз тенденцій ринку праці, розрахунок розривів у цифрових навичках і нормалізованих показників, сценарний аналіз, а також матрицю сильних і слабких сторін, можливостей і загроз. Результати засвідчили, що цифрові компетентності впливають на сталий розвиток через зростання продуктивності, посилення інноваційного потенціалу, економічну інклюзію, адаптивність ринку праці та інституційну стійкість. Особливу увагу було приділено оцінюванню цифрової трансформації України порівняно з Європейським Союзом та визначенню стратегічних пріоритетів політики, здатних зміцнити цифровий людський капітал у контексті європейської інтеграції та повоєнного економічного відновлення. Порівняльний аналіз показав, що Україна наближається до середнього рівня Європейського Союзу за базовими цифровими навичками, проте все ще стикається зі значними ризиками, пов'язаними з нерівномірним доступом, міграцією кваліфікованих працівників, недостатньою грамотністю у сфері штучного інтелекту та застарілими освітніми програмами. Розширене кількісне оцінювання показало, що за умови збереження тенденції 2021-2025 років до 2030 року частка дорослого населення України, яке володіє щонайменше базовими цифровими навичками, може становити лише близько 64,4 %, що на 15,6 відсоткового пункту нижче рекомендованого цільового показника. У статті обґрунтовано, що стратегія розвитку цифрового людського капіталу України має поєднувати навчання впродовж життя, грамотність у роботі з даними, грамотність у сфері штучного інтелекту, STEM-освіту, цифрову інклюзію та розумну регіональну політику. Практична цінність дослідження полягає в запропонованій концептуальній основі для поєднання цифрових компетентностей із продуктивністю, конкурентоспроможністю та політикою відновлення

Ключові слова: перекваліфікація робочої сили; ШІ-грамотність; грамотність щодо даних; цифрова інклюзія; розумна економіка; зростання продуктивності

ECONOMICS OF DEVELOPMENT
Journal homepage: https://ecdev.com.ua/
ISSN: 1683-1942
E-ISSN: 2304-6155
Vol. 25, No. 3, 2026
UDC 331.101.6:314.7
DOI: 10.63341/econ/3.2026.58

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Modelling the impact of demographic changes on labour productivity and economic activity in Ukraine during wartime and post-war recovery

Abstract. The aim of the study was to analyse the impact of demographic changes on Ukraine's labour force and economic development during wartime and post-war recovery. The study was theoretical and empirical in nature and covered the period 2021-2025, whilst data from 2026 were used for certain indicators. The methodology was based on the application of statistical, comparative and scenario-based analysis of demographic and macroeconomic indicators, the calculation of an approximate labour productivity index based on real gross domestic product and the number of employees, as well as the use of a production function and a scenario-based model for decomposing economic output into labour and productivity components. The results showed that Ukraine's population fell from 40.998 million in 2021 to a projected 32.283 million in 2026, whilst the number of births decreased from 273.8 thousand to 168.8 thousand in 2025. At the same time, the current decline in the labour force was primarily driven by external migration, war-related losses and other factors reducing the labour supply, whilst the falling birth rate poses predominantly long-term demographic risks. Following a 28.8% fall in real gross domestic product in 2022, the economy began a gradual recovery, although the pace of economic growth remained volatile. The estimated real GDP index per officially employed worker, having fallen from 100 in 2021 to 80.9 in 2022, gradually rose to 87 in 2025, though it remained 13% below the pre-war level. Scenario modelling showed that, under conditions of active technological modernisation, the real output index could rise to 118.7% of the 2025 level by 2030, whilst under a pessimistic scenario it would fall to 90.3%. The practical significance of the study lies in the possibility of using the results obtained when formulating state demographic, social and economic policies aimed at restoring the labour force, increasing labour productivity and ensuring Ukraine's sustainable economic development

Keywords: migration; human capital; population; gross domestic product; labour force

INTRODUCTION

Full-scale war has brought about changes in Ukraine's demographic structure, accompanied by a decline in population, large-scale migration processes, a reduction in the number of people of working age, and a transformation in the regional distribution of the labour force. These processes have affected the functioning of the labour market, the level of employment, the availability of labour for enterprises, and economic performance. At the same time, the country's post-war recovery will require significant labour resources for the reconstruction of infrastructure, the development of production, and the achievement of sustainable economic growth.

Population decline, intensified migration, an ageing population and a shrinking proportion of economically active citizens pose long-term risks to Ukraine's economic development amidst the challenges of war and post-war recovery. N. Petrukha *et al*. (2024) investigated the impact of demographic transformations on economic processes. The authors analysed trends in population decline, changes in fertility rates, migration flows and the impact on the labour market, the investment climate, the budgetary system and the country's economic development. The authors concluded that population decline, rising migration and a shrinking economically active population were holding

Article's History: Received: 16.04.2026; Revised: 30.07.2026; Accepted: 01.09.2026; Published: 02.10.2026

Suggested Citation:
Muskeyev, P. (2026). Modelling the impact of demographic changes on labour productivity and economic activity in Ukraine during wartime and post-war recovery. *Economics of Development*, 25(3), 58-71. doi: 10.63341/econ/3.2026.58.

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back economic growth, reducing tax revenues and diminishing the country's investment attractiveness. The study also justified the need to adapt state policy to the new demographic conditions and identified areas for supporting Ukraine's recovery processes. Demographic trends and the impact on social and labour relations were analysed in a study by N. Dehtiar (2025), which found a sustained decline in population size, an increase in the proportion of older people, a gender imbalance in older age groups, and the negative impact of internal migration and mobilisation processes on the supply of labour to the economy. The author also identified the main challenges for employment and justified the need to develop mechanisms for adapting the labour market to new socio-economic conditions.

Demographic losses caused by the war have a significant impact on the formation of the labour force and the prospects for Ukraine's economic development. I. Shubala (2022) conducted research into the impact of demographic and migration factors on economic processes. The author analysed the consequences of war-induced migration flows, changes in the population structure and the impact on the labour market and the prospects for economic recovery. The study revealed that the loss of human capital, a decline in the economically active population, an increase in the demographic burden and the outflow of working-age citizens abroad may hinder the country's post-war recovery. The main demographic transformations in Ukraine in the context of the state's economic security, analysed by A.M. Shtangret & B.M. Vityk (2026), made it possible to compare demographic trends with those of European Union countries and to develop scenarios for future changes depending on the duration of hostilities. The study found that population decline, falling birth rates, an ageing population, migration losses and labour shortages have a negative impact on the tax base, economic productivity, innovation, competitiveness, and the country's prospects for post-war recovery.

Military hostilities are accompanied by an intensification of depopulation processes, increased population migration and a transformation of the age structure of society. The impact of demographic factors on economic processes was examined in the "Comprehensive Analysis of the Demographic Situation in Ukraine" conducted by D. Naporchuk (2024), which covered indicators of fertility, mortality, the age structure of the population, migration processes and trends in the size of the working-age population. The study found that demographic ageing, depopulation and mass migration lead to a reduction in the labour force, an increase in the demographic burden, a decline in labour productivity and a rise in the state's social expenditure. V. Veklych (2024) analysed the sex-age structure of Ukraine's population, trends in demographic ageing, fertility dynamics, migration processes and the impact on the economy's supply of labour resources. The study found that the decline in the working-age population, the rise in the proportion of older people, the outflow of labour abroad and the mismatch between labour supply and demand are exacerbating labour shortages and hampering economic growth.

The deterioration in demographic indicators in the context of war leads to a reduction in the labour force and places a greater strain on the socio-economic system. An analysis of the demographic situation in Ukraine during the war, carried out by I.V. Yaremina *et al.* (2023), involved assessing the scale of population migration, trends in birth and death rates, and identifying the main factors influencing population replacement. The results showed that military operations contributed to an intensification of depopulation processes, an increase in the outflow of the working-age population, a deterioration in the age structure of the population, and a heightened risk of labour shortages in the future. M.I. Khoroshev (2024) analysed changes in the demographic situation in Ukraine during the war by examining the dynamics of birth rates, mortality rates, migration processes and changes in the age and sex structure of the population. The analysis revealed a sustained decline in the birth rate, a deterioration in natural population growth indicators, significant migration losses and a reduction in the size of the working-age population. It was also established that the mass exodus of young people and economically active citizens, population ageing and changes in the demographic structure may have a negative impact on the labour market, the country's economic potential and the prospects for post-war recovery.

At the same time, there remains insufficient research into the quantitative assessment of the impact of demographic changes on labour productivity, as well as the development of economic and mathematical models to forecast the consequences for Ukraine's economic development during the war and in the post-war recovery period. The aim of this study was to conduct a comprehensive assessment of the impact of demographic changes on Ukraine's labour force and economic development in the context of full-scale war and post-war recovery. To achieve this aim, the following objectives were set: to analyse Ukraine's demographic and economic indicators during the war; to assess the impact of demographic changes on the labour force, labour productivity and economic activity; and to develop a scenario-based economic-mathematical model for assessing the possible consequences of demographic transformations for Ukraine's economic development.

MATERIALS AND METHODS

The study was of a theoretical and empirical nature and covered the period 2021-2025, during which large-scale demographic and socio-economic changes took place, caused by the full-scale war in Ukraine. The chosen time frame made it possible to compare pre-war indicators from 2021 with trends from 2022 to 2025 and to analyse changes in population size, the labour force, the state of the labour market, labour productivity and macroeconomic dynamics. Statistical analysis of the data was carried out using descriptive statistical methods, in particular by determining absolute and relative changes in indicators, conducting index analysis and comparing the values across individual years. For certain indicators relating to population size, external migration and labour shortages, data and estimates for 2026 were also used, as these reflected the current state of demographic processes and the labour market. The medium-term consequences of the decline in the labour force were assessed using scenario modelling of the dynamics of Ukraine's real output for the period 2026-2030.

The theoretical and methodological basis of the study was formed by the principles of economic theory concerning the interrelationship between demographic processes,

labour supply, human capital, labour productivity and economic development. For the theoretical interpretation of the impact of demographic changes on economic development, the Cobb-Douglas production function of the form (1):

$$Y = A \times K^{\alpha} \times (hL)^{\beta}, \quad (1)$$

where Y – output or real GDP; K – physical capital; L – the index of the number of officially employed workers; h – the level of human capital per worker; A – the technological and organisational factor; α and β – the parameters of output elasticity with respect to the respective factors.

The production function was used as a theoretical basis for interpreting the potential to offset the reduction in the labour component through the accumulation of human and physical capital, automation, and technological and organisational changes. No empirical estimation of the parameters α and β was carried out due to the lack of complete official statistical data on the individual components of the production function.

Demographic transformations were examined using methods of statistical and comparative analysis. The dynamics of Ukraine's population in 2021-2026 were analysed on the basis of data from the International Monetary Fund (2026). A comparison of annual indicators was used to determine the overall scale of population decline and to assess the associated narrowing of the potential labour force base. Natural population decline was defined as the difference between the number of births and deaths in the relevant year and was used to characterise the intensity of depopulation processes.

Changes in formal wage employment were analysed using data from the Pension Fund of Ukraine's Register of Insured Persons (2025a) on the total number of insured persons and the number of officially registered wage earners in 2021-2025. These indicators were used as a data source for assessing trends in formal wage employment. However, the indicators do not cover the self-employed, those in informal employment, the unemployed or other participants in the labour market; therefore, these indicators are not regarded as a measure of the total labour force or aggregate labour supply in Ukraine. Regional shifts in the distribution of the labour force, linked to internal population movements, the outflow of workers from frontline regions and the uneven distribution of economic activity, were analysed on the basis of M. Trachuk (2024). Structural changes in the labour market and the worsening labour shortage were examined taking into account analytical assessments by the National Institute for Strategic Studies (2025).

External migration processes were examined using a comparative analysis of the dynamics of decisions to grant temporary protection to Ukrainian citizens in European Union countries between 2023 and 2025, based on data from Eurostat (2026). These indicators were used to assess the intensity of new migration flows and to characterise the long-term impact of forced external migration on Ukraine's labour force. Ukraine's economic dynamics were analysed using indicators of changes in real GDP and GDP at current prices in the national currency and US dollars for the period 2021-2025. The analysis was based on data from the State Statistics Service of Ukraine (n.d.) and the International Monetary Fund (2026). The dynamic comparison method was used to analyse economic trends.

Following the outbreak of full-scale war, the State Statistics Service of Ukraine temporarily suspended the publication of the Labour Force Survey results, making it impossible to use comparable official indicators of the labour force size, labour force participation rate, employment rate, unemployment rate (according to ILO methodology) and potential labour force. In view of this, the study utilised available administrative indicators of official wage-earning employment, registered unemployment and labour shortages, which, whilst not a complete substitute for labour market statistics, do allow for the characterisation of certain trends in the functioning of the labour market under wartime conditions. The trends in the number of registered unemployed in 2021-2025 were analysed based on data from the Ministry of Finance, whilst the number of employees in 2021-2025 was analysed using data from the Pension Fund of Ukraine (2025a). Absolute and relative changes were determined for each indicator over the available period. The reduction in the number of registered unemployed was interpreted in the context of demographic losses, outward migration, mobilisation processes and a reduction in labour supply, rather than as direct evidence of an improvement in labour market conditions.

An index-based method was used to estimate labour productivity. Due to the lack of complete comparable data on the total number of employed persons, the productivity indicator was defined as the real GDP index per employed person registered in the Pension Fund of Ukraine system. The year 2021 was taken as the base year, for which the value of all indices was set at 100. The index of the number of employees was calculated using formula (2):

$$I_{L,t} = \frac{L_t}{L_{2022}} \times 100, \quad (2)$$

where $I_{L,t}$ – the index of the number of employees in year t; L_t – the number of employees in the relevant year; L_{2022} – the number of employees in the base year.

The real GDP index, with a base of 2021 = 100, was derived by successively applying the official annual rates of change in real GDP. The real GDP index per employee was calculated using formula (3):

$$I_{LP,t} = \frac{I_{Y,t}}{I_{L,t}} \times 100, \quad (3)$$

where $I_{LP,t}$ – the index of real GDP per employee; $I_{Y,t}$ – the index of real GDP; $I_{L,t}$ – the index of the number of employees.

The calculations were based on data from the State Statistics Service of Ukraine (n.d.), the International Monetary Fund (2026) and the Pension Fund of Ukraine (2025a). The resulting indicator was regarded as an approximate macroeconomic estimate of labour productivity, as it did not cover the self-employed, those in informal employment and other categories of the working population that were not represented in the administrative data used.

To assess labour shortages and structural mismatches between labour supply and demand, a descriptive analysis was carried out of current indicators relating to the number of vacancies, jobseekers, registered unemployed and the occupations experiencing the greatest labour shortages. Figures as at 1 June 2026 were used to characterise the

current balance between employers' demand and the available labour supply. To characterise the functioning of enterprises, recruitment policies and hiring plans, the findings of the "Labour Market Barometer 2025" study (GRC, 2026) were also summarised.

To investigate the relationship between demographic processes and economic development, scenario-based economic and mathematical modelling was applied, which made it possible to assess possible trajectories of change in real output under various combinations of labour force dynamics and labour productivity. The economic-mathematical modelling was carried out using a scenario-based decomposition of the real output index into labour and productivity components. Since the labour productivity index was defined in the study as the ratio of the real GDP index to the index of the number of employees (Formula 3), this ratio was algebraically transformed into the form shown in (4) for the construction of the scenario model:

$$Y_t = L_t \times LP_t, \quad (4)$$

where Y_t – the real output index; L_t – the index of the number of employees; LP_t – the labour productivity index.

The main limitation of the study is the lack of up-to-date and comparable official data on the labour force, employment, labour force participation and unemployment, calculated according to ILO methodology, following the start of the Russian Federation's full-scale armed invasion of Ukraine on 24 February 2022. The use of alternative estimates and expert assessments was limited due to differences in methodology, population coverage and the temporal comparability of such data. Consequently, these indicators could not be included in the scenario model, which reflects only that part of the relationship that can be quantified on the basis of available official information.

Demographic losses were reflected through changes in the labour component, whilst technological modernisation, automation, the accumulation of human capital and organisational adaptation of enterprises were reflected through changes in the productivity component. The scenario calculations were performed sequentially using formula (5):

$$Y_t = Y_{t-1} \times (1 + g_L) \times (1 + g_{LP}), \quad (5)$$

where Y_{t-1} – the index of real output in the previous year; g_L – the average annual rate of change in the number of officially employed workers; g_{LP} – the average annual rate of change in labour productivity. The base value of the index in 2025 was set at 100.

Three scenarios for Ukraine's economic development in 2026-2030 were formulated. The optimistic scenario envisaged an annual reduction in the number of officially employed workers by 0.5% and a 4% increase in labour productivity, subject to the partial return of migrants, active automation and investment in human and physical capital. The baseline scenario was based on a 1.5% annual reduction in the number of officially employed workers and a 2.5% annual increase in productivity, which corresponded to the persistence of labour shortages and gradual organisational and technological adaptation. The pessimistic scenario envisaged an annual reduction in the number of officially employed workers by 3% and a productivity increase of only 1%, assuming continued emigration, weak investment activity and limited technological modernisation. Assumptions regarding changes in the number of employees were formulated taking into account long-term estimates of the decline in the total population and the working-age population (Tverdostup, 2023; Order of the Cabinet of Ministers of Ukraine No. 922-r, 2024). Therefore, a figure of -1.5% is taken as the baseline, -0.5% as a more favourable scenario assuming a partial return of the population, and -3% as a stress scenario in the event of worsening migration and demographic losses. The baseline productivity growth rate of 2.5% was determined taking into account its estimated average annual growth rate for 2022-2025, which stood at approximately 2.4%. The values of 4% and 1% were used, respectively, to reflect accelerated and limited technological adaptation. The parameters of the scenarios are conditional estimates and are not regarded as statistically assessed forecasts or established cause-and-effect relationships.

RESULTS

Demographic transformations and the impact on Ukraine's labour force

Full-scale war has brought about significant changes to the demographic situation in Ukraine, manifested in a decline in population size, a fall in the birth rate and large-scale migration (Strelchenko *et al.*, 2024). These trends have directly influenced the formation of the country's labour force, the level of economic activity among the population and the prospects for post-war economic recovery. To assess demographic changes in Ukraine, population trends for 2021-2026 have been analysed (Fig. 1).

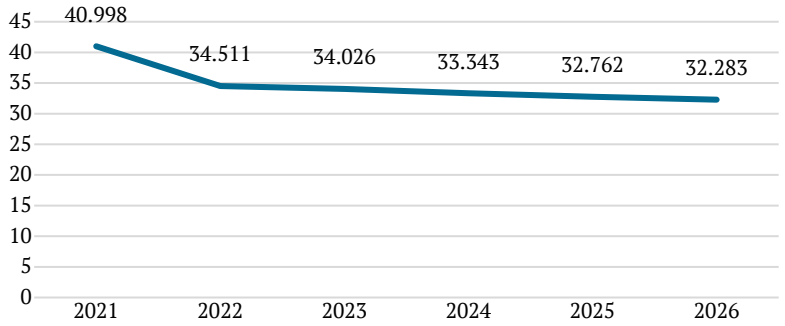


Figure 1. Population trends in Ukraine for 2021-2026, in millions

Source: compiled by the author based on data from the International Monetary Fund (2026)

According to Figure 1, Ukraine's population fell from 40.998 million to a projected 32.283 million between 2021 and 2026 – a decrease of almost 8.7 million people, or 21.3%. The sharpest decline occurred in 2022 following the outbreak of full-scale war, whilst in 2023-2026 the rate of population decline remained lower but steady. These trends indicate the persistence of long-term demographic losses, which are leading to a contraction in the country's labour force, exacerbating labour shortages and creating additional constraints on economic development and post-war recovery. Birth and mortality rates characterise population replacement processes and reflect demographic trends that influence the formation of the country's labour force (Park *et al.*, 2022). Against the backdrop of full-scale war, these indicators have undergone changes, which have affected the dynamics of natural population decline. To assess these changes, Table 1 presents the trends in birth rates, death rates and natural population decline in Ukraine for 2021-2025.

Table 1. Trends in birth rates and death rates in Ukraine for 2021-2025, in thousands

Year	Birth rate	Mortality	Natural population decline
2021	273.8	714.3	-440.5
2022	206	541.7	-335.7
2023	187.4	496.2	-308.8
2024	176.7	495.1	-318.4
2025	168.8	485.3	-316.5

Source: compiled by the author based on data from the Ministry of Justice of Ukraine (n.d.)

The data in Table 1 indicate a sustained decline in Ukraine's natural population growth rates between 2021 and 2025. The number of births fell from 273,800 in 2021 to 168,800 in 2025, a decrease of 38.3%. The sharpest decline was recorded in 2022 following the outbreak of full-scale war, when the birth rate fell by 24.8 % compared with the previous year. At the same time, the death rate remained higher than the birth rate throughout the entire period under review. Despite a reduction in the number of deaths from 714,300 in 2021 to 485,300 in 2025, the natural population decline in 2025 stood at 316,500.

These findings confirm the deepening of depopulation processes and a further decline in the country's demographic potential. At the same time, the decline in the birth rate between 2021 and 2025 cannot be regarded as the direct cause of the current labour shortage, as those born during this period will not yet have reached working age within the forecast horizon of the study. The current labour shortage is largely linked to external migration, mobilisation processes, war-related losses, internal population displacement and occupational-territorial imbalances, whilst the decline in the birth rate poses long-term risks to the replenishment of Ukraine's labour force.

Data from the Pension Fund of Ukraine's Register of Insured Persons (2025a) make it possible to track changes in the number of officially registered employees. According to available data, in December 2024 the total number of insured persons stood at 10.618 million, of whom 8.839 million were employees. By way of comparison, in December 2023 the number of employees stood at 8.906 million, and in December 2022 at 8.634 million. Consequently, following an increase in 2023, there was a slight decline throughout 2024, which, against a backdrop of a worsening labour shortage, points to limited scope for further expansion of formal employment. The mass exodus of citizens abroad, mobilisation processes, war-related losses and the internal displacement of the population have altered the age and geographical structure of Ukraine's labour force. This has resulted in an uneven distribution of labour resources across regions and an exacerbation of geographical imbalances in the labour market. Regions that have taken in a significant number of internally displaced persons have faced increased pressure on local infrastructure and labour markets, whilst frontline regions have been characterised by a decline in economic activity, an outflow of labour and a loss of productive capacity (Trachuk, 2024).

The scale of external migration among the Ukrainian population remains significant, although the intensity of new migration flows is gradually declining. According to the data, the number of decisions granting temporary protection to Ukrainian citizens in EU countries fell from 1.056 million in 2023 to 794,800 in 2024 and 683,500 in 2025 (Eurostat, 2026). At the same time, as of early 2026, there were around 5.9 million citizens outside Ukraine, indicating that forced external migration remains on a significant scale and continues to have a long-term impact on the country's labour force.

The decline in the working-age population has gradually transformed the structure of the Ukrainian labour market. According to estimates by the National Institute for Strategic Studies (2025), against the backdrop of structural changes in the labour market, the problem of labour shortages is becoming increasingly acute, exacerbated by demographic losses, large-scale external migration and mobilisation processes. At the same time, educational and vocational mismatches between the labour supply and employers' needs are becoming more pronounced, making it difficult for businesses to secure skilled workers and hindering the recovery of economic activity.

These processes have resulted in a worsening of the structural labour shortage in sectors that underpin the functioning of the economy and critical infrastructure. The greatest labour shortages are observed among skilled industrial workers, construction workers, drivers, electricians, welders and healthcare workers, whilst the available labour supply does not fully meet employers' needs. Consequently, demographic changes are affecting not only the size of the labour force but also its occupational and skills structure, which limits the potential for increasing labour productivity, complicates the provision of labour to enterprises and hampers Ukraine's post-war economic recovery.

Analysis of labour productivity and the functioning of the labour market in Ukraine

In addition to changes in population size and the structure of the labour force, demographic processes affect macroeconomic indicators, business activity and the functioning

of the labour market. In the context of the war, population decline, emigration, and a reduction in the labour force pose additional constraints on the country's economic development. To assess Ukraine's economic dynamics during the war, the trends in gross domestic product for 2021-2025 have been analysed (Table 2).

Table 2. Trends in Ukraine's real GDP and GDP volume for 2021-2025

Year	Real GDP, change, %	GDP at current prices, billion UAH	GDP at current prices, billion USD
2021	3.4	5,459.6	199.8
2022	-28.8	5,239.1	162
2023	5.5	6,628	181.2
2024	2.9	7,662.4	190.8
2025	1.8	8,876.7	212.9

Source: compiled by the author based on data from the State Statistics Service of Ukraine (n.d.) and the International Monetary Fund (2026)

The data in Table 2 show that Ukraine's economy experienced its deepest recession in 2022, after which a phase of gradual recovery began. At the same time, the trend in real GDP indicates a slowdown in economic growth, suggesting that structural constraints on economic development persist even after the most acute phase of the crisis has ended. One of the structural constraints on further recovery may be the reduction in the labour force due to demographic losses, large-scale emigration and labour shortages. Following the outbreak of full-scale war, the State Statistics Service of Ukraine temporarily suspended the publication of labour force survey results, which limited access to official data on the size of the economically active population, employment, and unemployment. Consequently, data on the number of registered unemployed persons were used to assess changes in the labour market. The relevant indicators are presented in Table 3.

Table 3. Selected administrative indicators of the Ukrainian labour market for 2021-2025

Year	Number of people with registered unemployed status at the end of the year, in thousands	Officially registered employees, in millions
2021	295	9.807
2022	186.5	8.634
2023	96.1	8.906
2024	94.2	8.839
2025	88.3	8.875
Absolute and relative change over the period	-206.7 people (-70.1%; 2025/2021)	-0.932 million people (-9.5%; 2025/2021)

Note: the number of registered unemployed covers only those who officially applied to the State Employment Service of Ukraine and had unemployed status as at the end of the relevant year; therefore, it does not reflect overall unemployment according to ILO methodology; this figure is not the same as the number of people who received unemployment benefits during December, as recorded in the Pension Fund of Ukraine's Register of Insured Persons; the number of employees, according to the Pension Fund of Ukraine, reflects official wage-earning employment, including those who received financial support, but does not include the self-employed or those in informal employment; it also differs from the broader category of persons who received wages, income, financial support, benefits, or compensation; the data presented are used solely to characterise specific administrative aspects of the labour market's functioning and are not subject to direct quantitative comparison

Source: compiled by the author based on data from the State Employment Service of Ukraine (2026) and the Pension Fund of Ukraine (2022; 2023; 2024; 2025b; 2026)

The data in Table 3 show that between 2021 and 2025, the number of registered unemployed fell significantly. At the same time, this indicator reflects only administratively registered unemployment and cannot be regarded as a measure of the overall level of unemployment in the country. This change occurred against a backdrop of large-scale external migration, mobilisation processes, demographic losses and a reduction in labour supply; therefore, it does not in itself indicate an improvement in the labour market situation. According to data from the Pension Fund of Ukraine's Register of Insured Persons, the number of officially registered employees fell from 9.807 to 8.875 million between 2021 and 2025, a decrease of 9.5%. The sharpest decline occurred in 2022, after which the figure remained relatively stable at between 8.8 and 8.9 million people. The continued high demand for workers from employers, coupled with reports of labour shortages, points to the existence of structural imbalances in the labour market, whereby administrative indicators of official employment do not fully reflect the true scale of the labour shortage (Han & Lee, 2020).

The administrative indicators provided do not allow for a direct assessment of labour productivity. To provide a rough macroeconomic assessment of the relationship between economic dynamics and the utilisation of labour resources, an index of real GDP per employee was calculated for the period 2021-2025. The year 2021 was chosen as the base year, as it was the last full pre-war year, enabling an assessment not only of the pace of recovery following the 2022 downturn, but also of the extent to which the economy is approaching its pre-war level of productivity. Due to the lack of complete comparable labour force survey data after 2022, the real GDP index per employed person

registered in the Pension Fund of Ukraine system has been used as a proxy indicator of labour productivity. To ensure comparability, the number of employees in December of the relevant year was used, taking into account those in receipt of monetary allowances. The results of the calculation are presented in Table 4.

Table 4. Estimated trends in labour productivity in Ukraine for 2021-2025

Year	Real GDP index, 2021 = 100	Number of employees, million	Index of the number of employees, 2021 = 100	Real GDP index per employee, 2021 = 100
2021	100	9.807	100	100
2022	71.2	8.634	88	80.9
2023	75.1	8.906	90.8	82.7
2024	77.3	8.839	90.1	85.8
2025	78.7	8.875	90.5	87

Note: the number of employees is given as at December of the relevant year; the real GDP per employee index is calculated as the ratio of the real GDP index to the number of employees' index; this indicator is an approximate macroeconomic estimate, as it does not cover the self-employed, those in informal employment and other categories of the working population

Source: calculated by the author based on data from the State Statistics Service of Ukraine (n.d.), the International Monetary Fund (2026) and the Pension Fund of Ukraine (2022; 2023; 2024; 2025a; 2025b; 2026)

The results of the calculations show that in 2022, the real GDP per employee index fell to 80.9% of the 2021 level, as the decline in real GDP was significantly greater than the reduction in the number of officially employed workers. Between 2023 and 2025, the indicator rose gradually: to 82.7% in 2023, 85.8% in 2024 and 87% in 2025. Consequently, compared with the low point in 2022, estimated labour productivity rose by approximately 7.5%; however, in 2025 it still remained 13% below the pre-war level of 2021. This trend indicates a gradual recovery in output per worker, but does not provide grounds for claiming a full return to pre-war productivity levels.

At the same time, the growth in estimated productivity should not be interpreted unambiguously as a sustained technological improvement in the economy's efficiency. Under wartime conditions, it may have been partly driven by a reduction in the workforce, an increase in the workload on existing staff, and the uneven recovery of individual sectors. Consequently, the growth in output per employee was accompanied by a worsening labour shortage and the risk of excessive labour intensification. In the long term, offsetting demographic losses requires not only a more intensive use of the existing labour force, but also the accumulation of human capital, the renewal of fixed capital and the acceleration of technological development.

From the perspective of the production function, output is determined by the interaction of physical capital, human capital and the technological-organisational factor. A reduction in the number of workers diminishes the available labour supply; however, its negative impact can be partially offset by capital accumulation, the upskilling of workers, automation, and growth in total factor productivity. In formal terms, this relationship can be represented by a production function:

$$Y = A \times K^{\alpha} \times (hL)^{\beta},$$

where Y – output or real GDP; K – physical capital; L – the labour force; h – the level of human capital per worker; A – the technological and organisational factor; α and β – the elasticity parameters of output with respect to the respective factors.

In the Ukrainian context, demographic losses primarily reduce the L component, whilst the migration of skilled workers, disruptions to educational pathways and limitations on vocational training may have a negative impact on the h component. The economy's ability to sustain output depends on the extent to which the reduction in the labour force is offset by the accumulation of human and physical capital, automation, and technological and organisational changes.

Further evidence of the decline in Ukraine's labour potential is the deepening labour shortage in the labour market. It is estimated that, to ensure long-term economic growth and post-war recovery, the country's economy will require around 4.5 million additional workers in the long term. As at 1 June 2026, there were 241,000 job vacancies listed on the Unified Job Portal, whilst only 141,000 people were seeking work through the State Employment Service of Ukraine (2026), of whom 94,000 had the status of registered unemployed. On average across the country, there were 17 vacancies for every 10 jobseekers, indicating that demand for labour exceeded supply. The most acute shortage was observed among skilled workers, in particular seamstresses, drivers, electricians, fitters, track fitters, turners, welders, and car mechanics. Such trends confirm the emergence of structural imbalances in the labour market, whereby the occupational and skills profile of the available workforce is increasingly out of step with the needs of the economy.

The results of the "Labour Market Barometer 2025" survey provided further evidence of sustained economic activity in Ukraine in 2025. According to the survey, 91% of companies continued to operate at full capacity – 5 percentage points more than in the previous year – whilst a further 8% of enterprises were operating at reduced capacity and planned to resume full operations. Revenue growth was reported by 33% of companies, which is 5 percentage points higher than in 2024, whilst 28% of enterprises reported stable revenues, which was 6 percentage points higher than the previous year's figure. At the same time, 95% of employers were recruiting staff, compared with 88% of companies in 2024. Almost half of the enterprises were recruiting staff across all areas of the operations, and 99% of organisations reported the intention to continue recruiting staff in 2026. At the same time, labour shortages remained one of the main challenges for businesses: 37% of companies noted a shortage of candidates for blue-collar roles, whilst 58% of employers reported a shortage of

staff across all categories. Among the main priorities for businesses in 2025 were retaining the workforce (65% of companies), maintaining competitive pay levels (61.6%) and retaining existing sales markets (47.7%). These figures indicate a gradual recovery in business activity, which occurred alongside a worsening labour shortage and increased competition for workers (GRC, 2026).

The findings suggest that, in the context of the war, Ukraine's economic activity is increasingly determined not so much by the quantitative parameters of the labour force as by the ability of enterprises to adapt to its shortage. The reduction in the labour force is accompanied by a structural transformation of the labour market, whilst maintaining production volumes requires a more efficient use of human capital, the modernisation of the production base and the introduction of technological solutions. This confirms the validity of applying economic-mathematical approaches to assess the impact of demographic changes on labour productivity and Ukraine's economic development.

A scenario-based model for assessing economic dynamics in the context of changes to the labour component of the economy

The analysis carried out has shown that, given the existing statistical limitations, the quantitative assessment of the impact of individual demographic indicators on economic development was conducted in the form of a hypothetical scenario-based assessment of economic dynamics under different rates of change in the number of officially employed workers. Therefore, including population size, fertility, natural decline, migration, and the labour force in a single regression model is methodologically inappropriate, as these indicators partly reflect the same demographic processes. To avoid conceptual duplication of explanatory variables and the problem of multicollinearity, the study employs a scenario-based model decomposing economic output into labour and productivity components:

$$Y_t = L_t \times LP_t,$$

where Y_t – the real output index; L_t – the index of the number of employees; LP_t – the labour productivity index. Within the model, demographic losses are reflected through changes in the labour component L_t, whilst technological modernisation, automation, staff upskilling and organisational adaptation of enterprises shape the dynamics of the component LP_t.

In the proposed model, demographic processes are not introduced as separate independent variables. The impact is realised indirectly through changes in the number of employees (the component L_t). This approach is consistent with the logic of the production function, since a decline in population size, a deterioration in the age structure, outward migration and a reduction in labour force participation primarily affect labour supply, which is partly reflected in the model by the index of the number of officially employed workers. Consequently, the scenarios reflect not the direct impact of individual demographic indicators, but the cumulative effect, realised through changes in the labour component of economic output.

The proposed approach is consistent with the production function, according to which a reduction in labour resources can only be offset by growth in human capital, the renewal of physical capital and improvements in technological efficiency. Unlike regression analysis based on a limited number of annual observations, the scenario model does not involve establishing cause-and-effect coefficients, but is used to identify possible trajectories of economic development under different combinations of employment and labour productivity trends. To implement the scenario-based approach, three variants of changes in the number of people in employment and labour productivity for the period 2026-2030 were formulated. The parameter values were defined as conditional estimates reflecting varying intensities of demographic losses, the return of the working-age population, investment activity and the technological adaptation of enterprises. The parameters of the optimistic, baseline and pessimistic scenarios are set out in Table 5.

Table 5. Parameters for scenario-based modelling of Ukraine's economic development in 2026-2030

Scenario	Average annual change in the number of employees, %	Average annual change in labour productivity, %	Economic rationale
Optimistic	-0.5	+4	Partial return of migrants, active automation, investment in human and physical capital
Base case	-1.5	+2.5	Persistence of labour shortages and gradual organisational and technological adaptation
Pessimistic	-3	+1	Continued labour outflow, weak investment and limited technological modernisation

Source: compiled by the author based on M. Tverdostup (2023), Order of the Cabinet of Ministers of Ukraine No. 922-r (2024) and the results of the calculations set out in Table 4

The values of the scenario parameters are not statistical forecasts of the number of officially employed workers or labour productivity, but rather define the boundaries of a hypothetical scenario range. The demographic component has been calibrated on the basis of official and analytical estimates of long-term changes in Ukraine's population. In accordance with Order of the Cabinet of Ministers of Ukraine No. 922-r (2024), the population may decline from 35.8 million in July 2024 to 28.9 million by the start of 2041, corresponding to an average annual rate of decline of approximately 1.3%. According to the results of scenario modelling by M. Tverdostup (2023), the decline in the working-age population between 2021 and 2040 could amount to 22.6-25.2%, or approximately 1.3-1.5% on an annual average basis. Therefore, the figure of -1.5% has been adopted as the baseline parameter for changes in the number of officially employed workers. The optimistic figure of -0.5% reflects a possible slowdown in this process due to the partial return of forced migrants, the mobilisation of internal labour market reserves and the expansion

of formal employment. The pessimistic figure of -3% has been used as a stress scenario, assuming a continued outflow of migrants, a limited return of the working-age population and a deepening of age-related imbalances. The demographic estimates were not equated with the forecast for officially employed labour, but were used to determine the direction and limits of its possible changes. The baseline labour productivity growth rate of 2.5% was determined taking into account the actual trend in the estimated index of real GDP per officially employed worker: in 2022-2025, its average annual growth rate was approximately 2.4%. The figure has been rounded to 2.5% and used as a benchmark for maintaining the established recovery trajectory. The optimistic figure of +4% assumes an acceleration in automation, technological modernisation and investment in human and physical capital, whilst the pessimistic figure of +1% reflects weak investment activity and limited scope for technological adaptation. The upper and lower limits have been set for the purpose of analysing the sensitivity of the model's results, rather than as the boundaries of a statistical confidence interval.

The scenario parameters reflect different relationships between the reduction in the labour component and the increase in labour productivity. The optimistic scenario assumes that active technological modernisation and investment in human capital will ensure a productivity gain sufficient to offset a slight reduction in the number of employees. The baseline scenario characterises a moderate adaptation of the economy whilst labour shortages persist, whereas the pessimistic scenario envisages labour losses outweighing the productivity gains. Based on the defined parameters, scenario-based calculations of the dynamics of the real output index were carried out, the results of which are presented in Table 6.

Table 6. Scenario-based trends in the real output index for 2026-2030, 2025 = 100

Year	Optimistic	Base	Pessimistic
2025	100	100	100
2026	103.5	10	98
2027	107.1	101.9	96
2028	110.8	102.9	94
2029	114.7	103.9	92.1
2030	118.7	104.9	90.3

Source: calculated by the author based on the scenario parameters given in Table 5

The results of the scenario modelling show that the impact of a reduction in the labour force on economic dynamics depends on the economy's ability to ensure sustained growth in labour productivity. Under the optimistic scenario, a 0.5% annual reduction in the number of employees is offset by a 4% increase in labour productivity, resulting in the real output index rising to 118.7% of the 2025 level by 2030. Such a trajectory is possible provided there is active technological modernisation, the return of part of the working-age population, the expansion of vocational training and a revival of investment activity.

Under the baseline scenario, an annual 1.5% decline in the number of employees is combined with a 2.5% increase in labour productivity. In this case, the compensatory effect remains limited, and the real output index rises to only 104.9% by 2030. This result indicates that a moderate increase in productivity makes it possible to sustain economic growth, but does not create a sufficient buffer for rapid post-war recovery. Under the pessimistic scenario, a 3% annual decline in the number of people in employment is not offset by a 1% increase in labour productivity. As a result, the real output index falls to 90.3% of the 2025 level. This points to the risk of labour shortages evolving from a local constraint on business activity into a systemic factor reducing potential output.

Consequently, it is not the decline in population itself that determines economic dynamics, but the relationship between the rate of decline in the labour force and the growth in labour productivity. If productivity growth exceeds the loss of the labour component, the economy can maintain positive output growth even under unfavourable demographic conditions. If technological and organisational adaptation proceeds more slowly than the rate at which the number of people in employment is falling, demographic losses will become a long-term constraint on economic development.

DISCUSSION

Demographic processes are among the factors that directly influence the formation of the labour force, labour productivity and opportunities for economic development. The results of this study have shown that demographic changes have influenced economic activity and the potential for economic development. A similar relationship between demographic processes and economic growth was noted by N. Jain *et al.* (2025), who viewed the demographic transition as a source of the demographic dividend through changes in the age structure of the population. In contrast, this study has shown that, for Ukraine, population decline, outward migration and a reduction in the labour force have become factors contributing to labour shortages and additional constraints on economic recovery.

I.T. Jumaniyazov & S.B. Abdulazizov (2025) analysed a completely different demographic situation. Whilst the findings of this study indicated a decline in Ukraine's population, a reduction in the labour force and an increase in emigration, in Uzbekistan the authors observed steady growth in population, the labour force and GDP between 2013 and 2023. Despite these differences, both studies confirmed that demographic processes had a direct impact on economic dynamics and the labour market. At the same time, this study focused on assessing the scale of demographic losses and conducting a scenario-based evaluation of the potential economic consequences. Both this study and the work by X. Hao *et al.* (2025) established the impact of the working-age population on economic development. However, the authors demonstrated that an increase in the proportion of the working-age population in China

contributed to economic growth, whilst the modernisation of the economy amplified this effect. In this study, the opposite trend was observed: a decline in Ukraine's population from 41 million in 2021 to 32.3 million in 2026, a reduction in the labour force, and migration losses had a negative impact on economic activity and the prospects for post-war recovery. Thus, whilst X. Hao *et al*. investigated positive demographic potential, the present study focused on the consequences of demographic losses.

A comparison with H. Gu *et al*. (2026) showed that similar demographic challenges can have different consequences. The authors found that the negative impact of population ageing in China was partly offset by the development of human capital and the upskilling of the workforce. In this study, the main problem was not only population ageing, but above all its rapid decline and the shrinking labour force, which led to labour shortages and hampered economic recovery. The study most closely related to this one in terms of subject was that by S. Yao *et al*. (2026), which also analysed the consequences of a shrinking labour force. The authors found that population ageing in China reduced corporate employment due to rising labour costs and the substitution of labour with capital. In that study, the negative impact on the labour market was linked to war-induced depopulation, migration, and a decline in the working-age population. Despite the different causes, both studies showed that a reduction in the labour force posed risks to economic development.

H. Al Naqbi *et al*. (2024) examined labour productivity from a technological perspective and demonstrated that generative artificial intelligence facilitated the automation of tasks and improved work efficiency. The findings of this study did not contradict this approach, but explained changes in labour productivity through a different mechanism. It was established that population decline, migration losses and a reduction in the labour force were weakening Ukraine's labour potential and limiting the scope for economic recovery. Thus, whilst H. Al Naqbi *et al*. analysed the technological factors driving productivity growth, this study demonstrated that demographic processes can constrain it regardless of the level of technological development. Another approach was proposed by W. Lai *et al.* (2023), who linked changes in labour productivity to climatic factors. The authors found that extreme temperatures had a negative impact on workers' physical and cognitive productivity. The results of this study were consistent with these findings regarding the negative impact of external factors on labour productivity; however, in the case of Ukraine, these factors were population decline, emigration and labour shortages, rather than climatic conditions. The findings of this study also partially aligned with the conclusions of F. Dell'Acqua *et al*. (2026), who found that generative artificial intelligence improved the speed and quality of task performance. At the same time, this study examined labour productivity through the lens of demographic changes, which were accompanied by population decline, migration losses and a reduction in the labour force. Thus, whilst F. Dell'Acqua *et al*. focused on factors driving productivity growth, this study demonstrated that demographic losses can constrain productivity even in the presence of potential for technological modernisation.

In this study, demographic changes were considered as a factor limiting Ukraine's economic activity due to population decline, migration losses and labour shortages. This was partly consistent with the findings of J.-D. Guénette & L. Shao (2025), who investigated the impact of demographic structure on labour productivity. At the same time, the work by J.-D. Guénette & L. Shao focused on age groups within the population, whereas this study showed that, for Ukraine, the decisive factors were war-induced depopulation, a decline in the population from 41 million in 2021 to 32.3 million in 2026, and a reduction in the labour force. Statistical analysis and scenario-based economic and mathematical modelling were used to assess these processes.

In the study by M. Dotsey *et al*. (2025), demographic processes were considered as a factor in China's economic growth through the accumulation of human capital and interaction with industrial policy. This study revealed a different nature of the impact of demographic processes on the economy. The decline in population and the labour force did not create an additional resource for development, but rather exacerbated labour shortages and hampered Ukraine's post-war recovery. The findings of C. Li & X. Li (2025) differed from those of this study in that population ageing in the Yangtze River Delta conurbation had a non-linear positive impact on economic growth through increased labour productivity and spatial spillover effects between regions. In contrast, in this study, population decline, migration losses and a reduction in the labour force led to labour shortages and constrained economic recovery. Therefore, the study focused on the consequences of war-induced depopulation rather than on the positive effects of demographic changes. Similar differences were also observed in comparison with the work by C. Wu *et al*. (2025). The authors found that population ageing in China may have increased labour productivity through automation and rising capital-labour ratios. In this study, the labour shortage was also a result of demographic changes; however, it was accompanied by increasing imbalances in the labour market. Ukraine's population decline and the reduction in its labour force were regarded as factors limiting economic activity and recovery prospects.

A broader macroeconomic context for interpreting the results is provided by the study by W. Liu & W. McKibbin (2020). The authors examined the global implications of demographic changes and demonstrated that young economies could benefit from the demographic dividend, whilst population ageing slowed economic growth and affected international capital flows. This study confirmed that demographic trends had long-term economic consequences, but applied this analysis to the Ukrainian wartime context. Here, the decisive factors were not global differences between young and ageing economies, but rather a sharp decline in population, migration losses and labour shortages. Unlike W. Liu & W. McKibbin, this study had an applied national focus and included scenario modelling of the potential economic consequences of demographic changes up to 2030.

In the paper by I. Calvo-Sotomayor & E. Atutxa (2025), the ageing of the workforce was viewed as a process whose impact depended on digitalisation, the sectoral structure of the economy and the transition to more knowledge- and

capital-intensive activities. This was partly consistent with the findings of this study regarding human capital and the adaptation of economic policy to demographic changes. At the same time, the key challenge for Ukraine was not the ageing of the population, but its rapid decline and the large-scale outflow of working-age citizens abroad. É. Berde *et al*. (2025) analysed the consequences of the exhaustion of the first demographic dividend in several countries and found that investment in human capital could partially mitigate the negative impact of population ageing on economic growth. This study also examined the role of human capital, but the main focus was on the consequences of war-induced depopulation. It was found that the decline in population and the labour force created additional risks to economic activity and economic development.

A comparison with E. Kokkinopoulou *et al*. (2026) revealed another aspect of labour potential. The authors demonstrated that education contributed to increased labour productivity, innovation, and competitiveness. In this study, human capital was also considered as a prerequisite for economic recovery; however, the main focus was on the decline in the number of people possessing it. The reduction in the population from 41 million to 32.3 million and the contraction of the labour force indicated a narrowing of the country's labour potential. In the study by P. Cuadrado *et al*. (2023), population ageing in Spain was linked to a decline in labour force participation. This study also revealed the negative impact of demographic processes on economic activity; however, in Ukraine, the reduction in labour supply was driven not only by ageing but also by the war, emigration, mobilisation and depopulation. Whilst in Spain immigration partially offset labour force losses, in this study migration was identified as one of the factors contributing to the decline in the labour force.

A study by V. Šipilova *et al*. (2025), which examined the decline in the working-age population in Latvia, was thematically similar. Both studies showed that demographic decline led to labour shortages and imbalances in the labour market. At the same time, V. Šipilova *et al*. analysed the long-term factors behind these processes, whilst this study assessed the consequences of the war-induced depopulation of Ukraine in 2021-2026 and used scenario analysis to evaluate the potential implications of demographic changes for economic development up to 2030. Another aspect of economic development was examined by A. Gómez-Tello *et al*. (2025), who investigated regional differences in labour productivity across Europe. The authors identified the influence of agglomeration effects, capital-intensity and knowledge generation. This study overlapped with that work only in terms of the analysis of labour productivity and human capital. However, whilst A. Gómez-Tello *et al*. explained productivity by the spatial concentration of resources and knowledge, in this study its limitations were linked primarily to demographic losses, a shrinking labour force and a skills' shortage.

The analysis showed that demographic changes influenced economic activity, labour productivity and the long-term prospects for economic development. Regardless of differences across countries, time periods and methodological approaches, most studies demonstrated a close interrelationship between demographic processes and the functioning of the labour market. At the same time, the nature of this impact proved to be varied. In a number of countries, the growth in the proportion of the working-age population, the development of human capital, the modernisation of the economy, the automation of production and rising educational levels among the population created the conditions for sustaining labour productivity and economic growth. In contrast, the findings of this study indicate that, for Ukraine, the determining factors were war-induced depopulation, large-scale outward migration and a reduction in the size of the labour force.

CONCLUSIONS

This study has shown that demographic transformations have become one of the key factors in the decline of Ukraine's labour potential and the emergence of long-term constraints on economic development. Between 2021 and 2026, Ukraine's population fell from 40.998 to 32.283 million people, a decrease of 21.3%, whilst the number of births fell by almost 38%. These changes indicate a deepening of depopulation processes, a narrowing of the labour force reproduction base and increased risks to post-war economic recovery.

An analysis of the labour market has shown that the reduction in registered unemployment by more than 70% does not reflect an improvement in the employment situation. It occurred simultaneously with a reduction in labour supply, large-scale emigration and a worsening of professional and skills imbalances. As a result, labour shortages are becoming structural in nature and are increasingly hampering the resumption of production activities and the provision of skilled workers to enterprises.

Macroeconomic analysis has shown that, following a 28.8% fall in real GDP in 2022, the economy entered a phase of gradual recovery, although the pace of growth has been gradually slowing. The estimated real GDP index per employee, having fallen from 100 in 2021 to 80.9 in 2022, rose to 87 in 2025. Consequently, compared with the low point in 2022, the figure has risen by approximately 7.5%, but has not yet reached pre-war levels. This trend reflects the economy's gradual adaptation to labour shortages, but cannot be regarded as an unconditional result of sustained technological productivity growth.

Scenario modelling has confirmed that the decisive factor in future economic dynamics is the relationship between the rate of decline in the labour force and the growth in labour productivity. Under conditions of active technological modernisation, the real output index could rise to 118.7% of the 2025 level by 2030, whereas under a pessimistic scenario it would fall to 90.3%. This indicates that it is precisely the increase in labour productivity that is capable of partially offsetting the negative consequences of demographic losses, whilst insufficient technological and organisational adaptation turns these into a long-term constraint on economic development.

A limitation of the study is the restricted availability of official statistical data under martial law, which necessitated the use of approximate macroeconomic indicators of labour productivity and scenario modelling instead of a full-scale econometric assessment. Prospects for further research relate to the development of sectoral and regional economic-mathematical models and the assessment of the impact of human capital, technological change and

migration processes on labour productivity and economic growth in Ukraine.

FUNDING
None.

ACKNOWLEDGEMENTS
None.

CONFLICT OF INTEREST
None.

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Моделювання впливу демографічних змін на продуктивність праці та економічну активність в Україні в умовах війни та післявоєнного відновлення

Анотація. Метою дослідження було проаналізувати вплив демографічних змін на трудовий потенціал та економічний розвиток України в умовах війни й післявоєнного відновлення. Дослідження мало теоретико-емпіричний характер і охоплювало період 2021-2025 рр., а для окремих показників використовувалися дані 2026 року. Методологія ґрунтувалася на застосуванні статистичного, порівняльного та сценарного аналізу демографічних і макроекономічних показників, розрахунку наближеного індексу продуктивності праці на основі реального валового внутрішнього продукту і чисельності найманих працівників, а також використанні виробничої функції та сценарної моделі декомпозиції економічного випуску на трудовий і продуктивнісний компоненти. Результати показали, що чисельність населення України скоротилася з 40,998 млн осіб у 2021 році до прогнозних 32,283 млн осіб у 2026 році, тоді як кількість народжених зменшилася з 273,8 тис. до 168,8 тис. осіб у 2025 році. Водночас поточне скорочення трудового потенціалу визначалося насамперед зовнішньою міграцією, воєнними втратами та іншими чинниками зменшення пропозиції праці, тоді як зниження народжуваності формує переважно довгострокові демографічні ризики. Після падіння показника реального валового внутрішнього продукту на 28,8 % у 2022 році економіка перейшла до поступового відновлення, однак темпи економічного зростання залишалися нестійкими. Розрахунковий індекс реального ВВП на одного офіційно найманого працівника після зниження зі 100 у 2021 році до 80,9 у 2022 році поступово зріс до 87 у 2025 році, однак залишався на 13 % нижчим за довоєнний рівень. Сценарне моделювання показало, що за умов активного технологічного оновлення індекс реального обсягу виробництва до 2030 року може зрости до 118,7 % від рівня 2025 року, тоді як за песимістичного сценарію він знижується до 90,3 %. Практичне значення дослідження полягає в можливості використання отриманих результатів під час формування державної демографічної, соціальної та економічної політики, спрямованої на відновлення трудового потенціалу, підвищення продуктивності праці та забезпечення стійкого економічного розвитку України

Ключові слова: міграція; людський капітал; чисельність населення; валовий внутрішній продукт; трудовий потенціал

ECONOMICS OF DEVELOPMENT
Journal homepage: https://ecdev.com.ua/
ISSN: 1683-1942
E-ISSN: 2304-6155
Vol. 25, No. 3, 2026
UDC 338.46:614.2:339.9
DOI: 10.63341/econ/3.2026.72

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Current issues in global health economics: Financing, equity, and resilience (literature review)

Abstract. The purpose of the study was to synthesise and critically evaluate current directions in global health financing, identify the principal points of tension between efficiency and equity, and assess how the financing agenda has been reshaped by climate change and pandemic risk. The study was based on a narrative synthesis of 42 scientific sources published mainly between 2010 and 2026, comprising policy reports, systematic reviews, and empirical studies indexed in major bibliographic databases, complemented by a smaller cluster of Ukrainian-authored literature on financing reform, informal payments, and system efficiency. The literature analysis showed that roughly 4.5 billion people still lack full access to essential health services, that efficiency-oriented reforms can widen socioeconomic inequalities in privately dominated systems, and that pandemic-preparedness funding is both underfinanced and geographically concentrated, with the African region receiving about 70% of total preparedness funding despite bearing a disproportionate share of the corresponding risk. Innovative financing instruments introduced between 2002 and 2015 mobilised approximately USD 8.9 billion, a modest share of overall development assistance for health, directed mainly toward vaccines and infectious-disease programmes rather than system strengthening. Climate finance was increasingly treated as a health-financing instrument rather than a purely environmental one, while low- and lower-middle-income countries would need to allocate roughly 37% and 9% of total health spending to meet global pandemic-preparedness targets under current financing patterns. The Ukrainian literature revealed a variant of these same problems: informal payments, underfinancing relative to GDP, and a post-reform financing model still being tested for its ability to combine competition among providers with equitable access. The review concluded that the central challenge for global health economics is no longer how much money is spent on health but how financing architecture, institutional capacity, and governance arrangements are matched to the setting in which they operate

Keywords: universal health coverage; health financing; equity-efficiency trade-off; pandemic preparedness financing; climate finance; health system resilience

INTRODUCTION

The economic organisation of health systems has become one of the most consequential policy problems of the twenty-first century. Health spending has risen almost everywhere over the past decade, yet this growth in financing volumes has not been matched by a corresponding improvement in the capacity of existing financing mechanisms to allocate resources efficiently, protect households financially, guarantee equitable access, and sustain the resilience of health systems under shock. This mismatch between the scale of resources mobilised and the performance of the mechanisms that allocate them is the central economic contradiction that this review examines. The 2023 global monitoring report jointly produced by the World Health Organization & The World Bank (2023) tracks coverage and financial-protection indicators across more than 190 countries and estimates that roughly 4.5 billion people still lack full access to essential health services, while catastrophic out-of-pocket spending continues to worsen rather than recede.

Using a global cross-country regression design linking a composite Universal Health Coverage (UHC) index to the disease burden of acute illness and injury,

Article's History: Received: 20.05.2026; Revised: 05.08.2026; Accepted: 01.09.2026; Published: 02.10.2026

Suggested Citation:
Petrashyk, Yu. (2026). Current issues in global health economics: Financing, equity, and resilience (literature review). *Economics of Development*, 25(3), 72-81. doi: 10.63341/econ/3.2026.72.

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K. Hajjar *et al*. (2023) found that greater coverage of essential services was strongly associated with a lower burden of disease, even though financial protection remained inadequate across most of the settings they studied; their conclusion is that expanding coverage without simultaneously strengthening risk pooling leaves the financial-protection half of the UHC objective largely unmet. The relevance of this problem was sharpened rather than created by the COVID-19 pandemic. A United Nations Executive Office of the Secretary-General (EOSG) (2020) policy brief concluded that the pandemic laid bare inadequate health systems, gaps in social protection, and structural inequalities that had existed long before 2020. That experience is one reason recent scholarship increasingly treats health expenditure less as a cost to be minimised and more as an investment in resilience, productivity, and social stability (World Health Organization & The World Bank, 2023; Dale *et al*., 2024).

At the same time, new financing pressures have emerged that were largely absent from the field a decade ago. Reviewing multilateral funds, environmental taxes, and adaptive social-protection schemes, J. Borghi *et al*. (2024) argued that climate change is a direct financing problem for health systems rather than a purely environmental one. Tracking global funding flows, H. Robertson *et al*. (2024) showed that pandemic-preparedness spending is geographically concentrated rather than allocated according to underlying epidemiological risk. Auditing national health accounts, R. Katz (2023) found, separately, that this same spending is difficult to measure through conventional accounting frameworks in the first place. And a 2026 narrative review of tax-based financing instruments in Sub-Saharan Africa by F. Mpofu & S. Chilunjika (2026) demonstrated that domestic revenue mobilisation has become a central rather than a marginal question for the field. A second, closely related current issue is the relationship between efficiency and equity in the allocation of health resources. J. Asamani *et al*. (2021) argued conceptually that these two objectives should be treated as complementary rather than conflicting, yet M. Bousmah *et al*. (2025), applying an efficiency-equity decomposition to two decades of OECD health spending panel data, find empirically that efficiency-seeking reforms can widen socioeconomic inequalities in health, particularly where private provision dominates service delivery, while also showing that reducing inequality can itself raise measured efficiency.

This tension between a conceptual claim of complementarity and empirical evidence of trade-offs runs through nearly every strand of the contemporary literature, from the financing of universal coverage to the design of pandemic-preparedness funds. The same tension is visible in the Ukrainian-authored literature that predates and parallels this global debate. Analysing hospital-payment governance during Ukraine's diagnosis-related-group reform, K. Karol *et al*. (2023) showed that formal payment rules alone did not improve resource allocation without parallel governance capacity at the facility level. E. Dale *et al*. (2024), documenting the resilience of Ukraine's primary care system through the COVID-19 pandemic and the subsequent full-scale war, argued that maintaining public financing and provider autonomy was the decisive factor that prevented system collapse under compounding shocks. M. Kuzheliev & A. Nechyporenko (2024) extended this Ukrainian literature to the financing side directly, concluding that Ukraine's health expenditure has grown in nominal terms but remains structurally exposed to global fiscal shocks because the underlying revenue base has not been diversified. Together, these Ukrainian studies confirm, at the country level, the same contradiction between financing volume and mechanism capacity identified in the global literature above.

Despite this expanding literature, three gaps remain. The UHC-financing, equity-efficiency, climate-finance, and pandemic-preparedness strands are typically reviewed separately, so the extent to which they compete for the same constrained fiscal space is rarely made explicit. Existing reviews also report qualitative conclusions about financing mechanisms without systematically comparing them against a common set of criteria – source and volume of resources, capacity to expand fiscal space, and effect on efficiency, equity, and financial protection. The Ukrainian-authored literature on financing reform, informal payments, and wartime resilience compounds this gap further: it is rarely read alongside the global literature, even though it documents the same underlying contradiction in a single, intensively studied setting. This review addresses these three gaps by bringing global UHC financing, climate- and pandemic-preparedness finance, and Ukraine-specific reform within a single comparative frame. The purpose of this article was to examine current approaches to financing health systems and to assess their effects on universal access, equity, efficiency, and system resilience. The specific objectives were: (1) to map the principal thematic clusters of the recent literature and to compare the quantitative financing indicators and financing needs reported across it; (2) to systematise the principal health-financing mechanisms identified in the review and their strategic functions; and (3) to examine how the Ukrainian-authored literature engages with these same problems under conditions of fiscal constraint and active war, and to draw out the resulting implications for the institutional transferability of financing models.

To address these objectives, the study employed a narrative review approach integrating the relevant literature within a common analytical framework. The review was based on a narrative synthesis of forty-two sources retrieved through Scopus, Web of Science, PubMed, and publisher databases (BMJ Global Health, The Lancet Global Health, Bulletin of the World Health Organization, Health Affairs Scholar, and others), supplemented by policy reports from the World Health Organization, the World Bank, the United Nations Executive Office of the Secretary-General (EOSG), and Oxfam International, and by a targeted subset of Ukrainian-authored journal articles and a doctoral thesis addressing health-financing reform, informal payments, and institutional transferability. Searches combined the terms "health financing", "universal health coverage", "equity-efficiency trade-off", "fiscal space", "climate finance AND health", "pandemic preparedness financing", and "Ukraine AND health reform", each cross-referenced with "review", "systematic", or "analysis" to prioritise synthesis-type and empirical sources over opinion pieces.

Sources were selected if they addressed health-system financing, universal health coverage, equity-efficiency trade-offs, climate or pandemic-preparedness finance,

or Ukrainian health-economy reform, and were published between 2010 and 2026, with priority given to work from the past five years. Sources were assigned to one of seven thematic clusters based on their primary object of analysis – the financing mechanism, population, or policy question each source addressed most directly – producing the classification summarised in Table 1; where a source covered more than one theme, it was assigned to the cluster corresponding to its stated primary contribution. The quantitative benchmarks and the financing mechanisms were extracted directly from the results reported in the reviewed sources and grouped by the type of indicator (coverage, cost, or financing share) and by financing instrument, respectively. Sources were synthesised narratively rather than through formal meta-analysis, consistent with the heterogeneous, largely policy-analytic and review-based nature of the underlying literature.

THEORETICAL APPROACHES TO HEALTH FINANCING AND RESOURCE ALLOCATION

Financing health systems was ultimately a question of how the mechanisms that mobilise resources, the fiscal space those mechanisms create, the way risk was pooled once resources are raised, and the rules that govern how resources were then allocated interact to shape four outcomes: efficiency, equity, financial protection, and the resilience of the system under shock. Examining these interactions involved considering three recurring issues discussed in the literature: health financing as an integrated system rather than a set of independent instruments; the relationship between economic efficiency and equity in resource allocation; and the institutional transferability of financing models across countries and systems. The conceptual starting point was A. Farlow's (2016) assessment, which organised global health economics around three questions: how to build more equitable health systems, how to manage common problems in health, and how to improve evaluation and priority setting. G. Yamey *et al*. (2019) sharpened the second of these questions into an explicit financing argument, holding that "global functions" in health are transnational by definition and that the World Health Organization occupies a unique position to provide overarching governance for their financing. A. Ruckert (2013) situated the political opening for this agenda historically, arguing that overlapping financial, environmental, and fiscal crises created a window for equity-oriented reform in global health governance after 2008.

Within this frame, health financing itself was best understood as an integrated policy stack rather than a set of independent instruments. S. Witter (2010) treated taxation-based funding, insurance schemes, user charges, costing, priority setting, payment systems, and public-private mix as components of a single connected system, and T. Ottersen *et al*. (2017) showed why these components cannot be separated in practice: where risk pooling is fragmented across multiple parallel schemes, households face high out-of-pocket costs regardless of how much aggregate revenue the system raises, a framing that recurs throughout the more recent literature on innovative financing (Atun *et al.*, 2012; Gartner, 2015) and on the transferability of financing models across institutional settings. The transferability problem was not a peripheral concern: O. Mandrik (2015) showed, using Ukraine as the principal example for Central and Eastern Europe and the former Soviet region, that health-economic evidence generated in one institutional and fiscal context frequently does not travel cleanly to another, which is one reason the same financing label – insurance, tax-based funding, blended instruments – can produce very different distributional outcomes depending on where it is applied.

The second concept – the relationship between efficiency and equity – was treated not as a fixed trade-off but as an empirical question whose answer depends on financing design. J. Asamani *et al*. (2021) framed the two objectives as complementary in principle, while M. Bousmah *et al*. (2025) showed empirically, using OECD panel data, that the relationship can run in either direction depending on the extent of private provision. These two positions are not simply contradictory; they describe different scope conditions. J. Asamani *et al*.'s (2021) complementarity claim held at the level of system design in general, whereas M. Bousmah *et al*.'s (2025) trade-off finding was conditional on how much of service delivery is privately provided. The contradiction between them supplies the first criterion this review uses to compare financing mechanisms below: not whether a mechanism raises efficiency or equity in the abstract, but under which institutional conditions – and specifically, under what degree of private provision – it delivers one, the other, or both.

A second theoretical strand concerns the instruments used to expand fiscal space for health. R. Krech *et al*. (2018) extended the integrated-system logic to private capital, arguing that incorporating health into environmental, social, and governance (ESG) investment criteria could draw mainstream financial-sector actors into global health investment. J. Michaud & J. Kates (2011) and D. Gartner (2015) took a more cautious position: innovative financing mechanisms are best understood as a supplement to, rather than a substitute for, traditional development assistance, and the mechanisms that endure over time tend to be the automatic, participatory ones that integrate resource mobilisation with pooling and allocation. A third strand critiques insurance-led approaches to universal coverage on distributional grounds. C. Averill & A. Marriott (2013) argued that premium-based health insurance schemes often exclude the poorest and most marginalised households, and that progressive taxation combined with international aid provides a more reliable route to equitable coverage. Taken together, these three concepts imply that no single financing instrument can be assessed in isolation: its contribution to fiscal space must be weighed against its effect on pooling, its distributional consequences, and the institutional setting in which it is implemented. The remainder of this review applies this three-part lens – integration, efficiency-equity balance, and transferability – to the empirical and policy literature on universal coverage, climate and pandemic financing, and Ukraine's own financing reform.

THEMATIC CLUSTERS IN HEALTH-FINANCING RESEARCH

The single most consistent "current issue" was the unfinished character of the UHC agenda. The 2023 global monitoring report estimates that approximately 4.5 billion

people still lack full access to essential health services, and that catastrophic out-of-pocket spending continues to increase rather than decline (World Health Organization & The World Bank, 2023). This is consistent with K. Hajjar *et al*. (2023), who found in a global cross-country analysis that greater coverage of essential services was strongly associated with a lower burden of disease from acute illness and injury, while financial protection remained inadequate across most of the settings studied. T. Ottersen *et al*. (2017) located the underlying mechanism in weak risk pooling: where pooling is fragmented, households face high out-of-pocket costs regardless of how much aggregate money flows into a health system. The COVID-19 pandemic, as the United Nations Executive Office of the Secretary-General (EOSG) (2020) policy brief argued, did not create these weaknesses but exposed them starkly, revealing gaps in social protection and structural inequality that had been present well before 2020. Table 1 summarises how this UHC-financing cluster relates to the six other thematic clusters identified in the literature reviewed.

Table 1. Thematic clusters identified in the reviewed literature

No.	Thematic cluster	Representative sources
1	Universal health coverage and financial protection	T. Ottersen *et al*. (2017), World Health Organization & The World Bank (2023), K. Hajjar *et al*. (2023)
2	Equity-efficiency trade-off	J. Asamani *et al*. (2021), R. Krech *et al.* (2018), M. Bousmah *et al.* (2025)
3	Climate finance as health finance	J. Borghi *et al*. (2024), S. Khanal *et al*. (2024), M. Reid & I. Katz (2025)
4	Pandemic-preparedness financing	R. Katz (2023), M. Shahid *et al.* (2024), N. Ndembi *et al*. (2024), R. Duran-Fernandez *et al*. (2024), H. Robertson *et al.* (2024)
5	Innovative financing instruments and fiscal space	R. Atun *et al*. (2012; 2017), J. Michaud & J. Kates (2011), D. Gartner (2015), F. Mpofu & S. Chilunjika (2026)
6	Institutional transferability and governance	S. Witter (2010), A. Ruckert (2013), O. Mandrik (2015), G. Yamey *et al*. (2019)
7	Ukraine-specific reform and financing	T. Stepurko *et al*. (2015), L. Deshko *et al*. (2020); K. Hrytsenko *et al*. (2021), L. Beztelesna *et al*. (2024), V. Smiianov *et al*. (2025)

Source: compiled by the author based on the reviewed literature

Reading these seven clusters together shows that they are not independent research agendas but different entry points into a single underlying problem. The UHC-financing cluster establishes that coverage expands only when pooling is strong enough to convert revenue into financial protection. The equity-efficiency cluster shows that the same revenue can be allocated in ways that either narrow or widen access gaps, depending on how private provision and pooling interact. The climate-finance and pandemic-preparedness clusters demonstrate that this allocation problem intensifies under shock, when several claims compete for the same fiscal space. The innovative-financing cluster catalogues the instruments available to expand that space in the first place. None of these clusters, taken on its own, explains financing performance by resource volume alone: each one instead traces performance back to how resources are mobilised, pooled, allocated, and administered – the institutional-capacity dimension that the transferability cluster (6) and the Ukraine-specific cluster (7) examine directly. Only clusters 2 and 4 report a direct empirical trade-off – between efficiency and equity, or between financing volume and geographic equity – while the remaining clusters largely argue for complementarity without testing it empirically.

BALANCING EQUITY AND EFFICIENCY

A second major thread was the equity-efficiency trade-off in the allocation of health resources. J. Asamani *et al*. (2021) argued that equity and efficiency should be treated as complementary policy goals rather than competing ones, since inefficient systems ultimately fail to deliver equitable access regardless of how resources are formally allocated. This optimistic reading is complicated by more recent evidence. A 2025 analysis of OECD countries found that efficiency-seeking reforms can widen socioeconomic inequalities in health, particularly in systems where private provision plays a dominant role, though the same analysis also found that reducing inequality can itself improve system efficiency (Bousmah *et al*., 2025). R. Krech *et al*. (2018) pushed the financing side of this debate further, arguing that financial-sector actors and ESG-style investment frameworks can mobilise additional resources for global health, provided that health is treated as a mainstream investment criterion rather than a residual social cost. Taken together, this literature suggests that the policy implication is not simply "spend more everywhere", but rather to design financing mechanisms that buy access, financial protection, and system performance rather than shifting risk onto households (Krech *et al*., 2018; Bousmah *et al*., 2025).

Comparing these three positions directly clarifies where they actually disagree. J. Asamani *et al*. (2021) made a conceptual claim about system design in general; M. Bousmah *et al*. (2025) tested a specific institutional condition – the share of private provision – and find that the conceptual claim holds only when private provision is limited, which means the disagreement is not about whether efficiency and equity can coexist but about which institutional settings make coexistence possible. R. Krech *et al*. (2018) addressed a different link in the causal chain: even a well-designed domestic financing mechanism still needs a revenue source, and private capital is one option for expanding that base without necessarily reproducing the private-provision effect that M. Bousmah *et al*. (2025) identified, since ESG-aligned investment can flow into public as well as private delivery channels. Read this way, the equity-efficiency literature does not describe a single trade-off but three separate design questions – the extent of private provision, the source of financing, and the strength of pooling arrangements – that jointly determine whether a given reform improves or worsens equity. This means no financing mechanism examined in this review can be judged by resource volume or efficiency gains alone:

the more decisive test is distributive – which groups capture the principal benefits, onto whom the residual financial risk is shifted, and whether access genuinely improves for socially and economically vulnerable populations, rather than efficiency gains being realised simply by pricing out the households least able to pay.

CLIMATE AND PANDEMIC-PREPAREDNESS FINANCING: COMPETING CLAIMS ON A CONSTRAINED FISCAL SPACE

Climate finance and pandemic-preparedness finance represent two increasingly important areas within global health financing, as both require additional resources to strengthen health-system resilience under growing external pressures. Although they are often discussed as separate policy agendas, both rely on the same constrained pool of domestic and international resources, which creates competition between them in fiscal terms rather than making them fully independent priorities. J. Borghi *et al*. (2024) argued that climate-finance mechanisms – multilateral climate funds, carbon and other environmental taxes, micro-levies, and adaptive social-protection schemes – can be used to generate health-sector resources and make health systems more resilient to climate-related shocks. This reframing matters because it treats adaptation finance and health finance as overlapping rather than separate budget lines, which is consistent with the broader equity case made elsewhere in the climate-and-health literature (Khanal *et al*., 2024; Reid & Katz, 2025). The distributional stakes are considerable: groups that contribute least to greenhouse-gas emissions, including women, children, and adolescents in low-resource settings, are expected to bear a disproportionate share of climate-related health harms, and B. Anton *et al*. (2024) showed that financing mechanisms specifically targeted at women's, children's, and adolescents' health remain underdeveloped relative to this exposure, which strengthens the argument for using climate-linked financing instruments to protect continuity of care and household financial protection rather than treating climate adaptation and health financing as competing claims on scarce fiscal space (Borghi *et al*., 2024).

Pandemic-preparedness financing has emerged as a distinct and rapidly growing subfield within global health economics, and it draws on the same fiscal-space logic. N. Ndembi *et al*. (2024) argued that global health security and universal health coverage will both remain out of reach unless African health systems are adequately funded for emergency resilience. R. Duran-Fernandez *et al*. (2024) screened a large body of literature on this question and found that the field remains concentrated on infrastructure and institutional systems, with comparatively little attention paid to vulnerable households or to the practical feasibility of specific financing instruments. Two measurement problems compound this gap: preparedness and response spending is not captured explicitly within conventional national health accounts, which makes the financing gap difficult to quantify with precision (Katz, 2023), and the funding that does exist has remained geographically patterned rather than strategically reallocated. H. Robertson *et al*. (2024) reported that the African region has received approximately 70% of total global preparedness funding, a concentration that does not straightforwardly track underlying epidemiological risk.

M. Shahid *et al*. (2024) converted this debate into an explicit feasibility question, modelling the financing implications of the World Bank/WHO pandemic preparedness and response (PPR) targets. Their central estimate is stark: under current financing patterns, low-income countries would need to devote approximately 37% of total health spending to PPR, and lower-middle-income countries approximately 9%, if the global targets are to be met, and they conclude that ordinary year-on-year growth in official development assistance cannot close this gap on its own. This is precisely the mechanism-level evidence for fiscal competition that the climate-finance literature describes only qualitatively: M. Yaghoubi *et al*. (2023), modelling fiscal-space expansion for financing treatment costs during biological crises, show that health systems facing simultaneous shocks exhaust conventional budget-reallocation options quickly and must rely on the same small set of instruments – reserve funds, emergency borrowing, and earmarked levies – that climate-adaptation financing also depends on. Read alongside M. Shahid *et al*. (2024), this indicates that climate adaptation and pandemic preparedness are not two separate calls on health budgets but two labels attached to overlapping fiscal instruments, so that financing one can crowd out the other unless additional, instrument-specific revenue is mobilised. Table 2 collects this and several other quantitative benchmarks from the literature reviewed, since numbers of this kind are the clearest evidence of how far current financing falls short of stated policy targets.

Table 2. Quantitative benchmarks from the reviewed literature

Indicator	Value	Source
Population lacking full access to essential health services (global)	~4.5 billion people	World Health Organization & The World Bank (2023)
Total funds mobilised via innovative financing instruments, 2002-2015	~USD 8.9 billion	R. Atun *et al*. (2017)
Share of total preparedness funding received by the African region	~70%	H. Robertson *et al*. (2024)
Health spending share required for PPR targets – low-income countries	~37% of health spending	M. Shahid *et al*. (2024)
Health spending share required for PPR targets – lower-middle-income countries	~9% of health spending	M. Shahid *et al*. (2024)
Peer-reviewed papers screened on pandemic-preparedness financing	188 screened, 60 included	R. Duran-Fernandez *et al*. (2024)

Source: compiled by the author

The benchmarks in Table 2 make the fiscal-competition argument concrete. An estimated USD 8.9 billion mobilised over thirteen years through innovative financing is small relative to the 37% and 9% of total health spending that M. Shahid *et al*. (2024) calculated low-income and lower-middle-income countries would need to devote to

pandemic preparedness alone, before any climate-adaptation costs are added. This gap between historical resource mobilisation and current financing needs is the empirical basis for treating climate and pandemic-preparedness financing as a single, shared fiscal-space problem rather than two separate policy agendas, and it is the reason the following section examines the instruments available to close that gap.

INNOVATIVE FINANCING INSTRUMENTS AND FISCAL SPACE

The older innovative-financing literature remains directly relevant because it supplies the toolkit that the newer climate- and pandemic-financing literatures continue to reuse. R. Atun *et al*. (2017) identified ten innovative financing instruments that mobilised approximately USD 8.9 billion between 2002 and 2015, a relatively modest share of overall development assistance for health, and found that most of this money was channelled to vaccine programmes and major infectious-disease initiatives rather than to broad health-system strengthening or non-communicable disease control. Their earlier work argues that the genuine innovation was not the additional revenue as such, but the creation of integrated financing mechanisms capable of mobilising, pooling, allocating, and channelling resources more effectively than fragmented project-based aid.

Domestic revenue mobilisation increasingly complements this external-financing literature. A 2026 review of innovative tax models in Sub-Saharan Africa identifies tobacco, alcohol, sugar-sweetened-beverage, environmental, digital-service, and resource-extraction taxes as plausible instruments for expanding fiscal space for health, while cautioning that weak tax administration, high informality, and unresolved equity concerns can blunt their effectiveness in practice (Mpofu & Chilunjika, 2026). Read together with the older critique of insurance-led universalism, which holds that premium-based schemes tend to exclude the poorest households and places progressive taxation and international aid at the centre of equitable coverage (Averill & Marriott, 2013), this literature points toward a common conclusion: the central financing question is shifting from "how do we raise more money for health?" to "which revenue instruments are politically feasible and administratively workable in a given setting?" (Averill & Marriott, 2013; Mpofu & Chilunjika, 2026).

Comparing the instruments discussed in this subsection against the criteria used throughout this review – source and volume of resources, capacity to expand fiscal space, and effect on efficiency, equity, and financial protection – shows why no single instrument dominates. Blended international instruments (Atun *et al*., 2012; 2017) mobilised large absolute sums but a small share of total need, and they are earmarked to specific diseases rather than general system strengthening, which limits their contribution to efficiency or equity beyond the programmes they target. Domestic "sin" and digital taxes (Mpofu & Chilunjika, 2026) can in principle be scaled to a country's own fiscal capacity and reach recurrent rather than one-off financing, but their yield is constrained by weak administration and informality, which are precisely the conditions most acute in the lower-income and transition economies that need the revenue most. Progressive general taxation (Averill & Marriott, 2013) scores best on equity and financial protection because it does not exclude informal-sector households the way premium-based insurance does, but it depends on a tax base and collection capacity that many of the same constrained settings lack. The practical implication is that fiscal-space strategies need to combine instruments with complementary weaknesses rather than search for one instrument that performs well on every criterion.

INSTITUTIONAL TRANSFERABILITY AND THE GOVERNANCE OF GLOBAL HEALTH FINANCE

A distinct strand of the literature asks whether health-economic evidence and financing models actually travel across institutional settings, rather than assuming that a model that performs well in one country can simply be imported into another. S. Witter (2010) provided a useful baseline by treating financing, taxation, insurance, user charges, payment systems, and priority setting as one connected policy stack rather than a set of independent design choices. O. Mandrik (2015) made the transferability problem explicit, using Ukraine as the principal example for Central and Eastern Europe and the former Soviet region, and argues that the evidence base underpinning many financing recommendations was generated in institutional, fiscal, and administrative contexts that differ substantially from those of transition economies. This has direct governance implications: who pools financing, who allocates it, and whose risk is protected are not merely technical questions but determine whether a given financing architecture produces equity or, as M. Bousmah *et al*. (2025) showed for OECD countries, a more efficient version of exclusion. This governance lens also explains why the same instrument – provider competition, for example, or blended international financing – can raise efficiency in one institutional setting while widening exclusion in another: the difference lies not in the instrument itself but in whether the surrounding institutions pool risk, protect the poor, and enforce accountability, which is exactly the transferability question O. Mandrik (2015) raised for Ukraine and Central and Eastern Europe.

Read across the literature, institutional transferability rests on five conditions rather than on the financing instrument itself. Administrative and tax capacity determines whether a mechanism can actually be collected and enforced at the revenue-mobilisation stage. The prevailing level of risk pooling determines whether new resources translate into financial protection or are simply absorbed by fragmented schemes. Regulatory capacity determines whether private or blended instruments are steered toward system goals rather than around them. Dedicated mechanisms to protect vulnerable groups determine whether efficiency gains are captured broadly or concentrated among households already able to pay. And system-level accountability – the ability to track where resources go and hold institutions responsible for outcomes – determines whether any of the preceding four conditions can be verified rather than assumed. Ukraine offers a direct test of this five-part framework: a transition economy with constrained administrative and tax capacity, a financing reform explicitly built around provider competition, and, since 2022, a war that

has stressed every one of these conditions simultaneously. The Ukrainian case examined in the next section shows how these institutional constraints play out in practice.

UKRAINE AS A CASE STUDY IN REFORM UNDER CONSTRAINT

The Ukrainian-authored literature is considerably smaller than the global literature reviewed above, but it engages directly with the same underlying problems of underfinancing, financial-risk protection, efficiency, and institutional reform. T. Stepurko *et al*. (2015) described informal payments in Ukrainian health care as a shadow-economy or "gray market" problem that functions as a regressive, unofficial user-charge system operating alongside formally free care. K. Hrytsenko *et al*. (2021) used efficiency-frontier and regression methods to show that financing problems in Ukraine cannot be solved without first assessing system efficiency directly, comparing Ukraine with other transition and developing economies. O. Zaliska & I. Irynchyna (2020) framed the development of Ukraine's national health economy as part of a broader process of global transformation rather than a purely domestic reform agenda.

More recent Ukrainian contributions are increasingly operational rather than conceptual. V. Harbyzuk *et al*. (2021) reported that public spending on health care over 2018-2020 lagged behind the growth of the broader economy, an early warning sign for the fiscal-space arguments. L. Deshko *et al*. (2020) framed Ukraine's reformed financing model around eight explicit principles: financial protection, universality, equity, transparency, accountability, efficiency, free choice, and competition among providers. L. Beztelesna *et al*. (2024) found empirically that the reform increased patient choice and the number of formal declarations signed with private healthcare facilities, evidence of a more competitive provider market, though this raises an open question about whether competition alone improves equitable access rather than simply reallocating existing demand. V. Smiianov *et al*. (2025) extended the discussion to wartime conditions, arguing that metropolitan health systems in Ukraine require quality optimisation grounded in economic determinants in order to avoid irrational and unjustified expenditure during a period of acute fiscal and infrastructural stress. A comparative study of foreign health-financing systems and Ukraine situates these domestic findings within a broader cross-national frame, using the experience of health systems observed between 2007 and 2016 rather than treating Ukraine as an isolated case (Kinash & Savchuk, 2019).

Two further strands of the domestic literature sharpen this picture. O. Kolotilina *et al*. (2022) traced the growth of private provision alongside the public Programme of Medical Guarantees and find that the state has so far regulated private entry only loosely, which helps explain why L. Beztelesna *et al*. (2024) observed rising competition without a corresponding policy lever to keep that competition equity-enhancing. Y. Volkova *et al*. (2024), analysing the financial statements of a sample of Ukrainian healthcare institutions, report that facility-level financial provision remains uneven across regions even after the 2018 financing reform, consistent with V. Smiianov *et al*.'s (2025) argument that wartime metropolitan systems still carry irrational and unjustified expenditure. The most recent authoritative assessment, a joint WHO/World Bank review of Ukraine's financing reform, finds that the reform has nonetheless strengthened system resilience overall, maintaining universal population coverage under the Programme of Medical Guarantees despite the economic, demographic, and epidemiological shocks of the war (World Health Organization & The World Bank, 2024). Read together with E. Dale *et al*.'s (2024) finding that continuity of public financing was the decisive factor in primary care resilience, the Ukrainian literature converges on a single conclusion: the 2018 financing architecture has proved resilient at the aggregate level, but the regional and facility-level unevenness documented by Y. Volkova *et al*. (2024) and V. Smiianov *et al*. (2025) showed that resilience at the system level has not yet translated into uniform equity at the point of care. Table 3 summarises the principal financing mechanisms discussed above and their strategic function within the broader agenda of universal coverage, equity, and resilience.

Table 3. Principal financing mechanisms

Financing mechanism	Strategic function	Illustrative sources
Progressive taxation and general revenue	Broadens risk pooling; protects households excluded by premium-based insurance	S. Witter (2010), C. Averill & A. Marriott (2013)
Innovative/blended financing instruments	Mobilises earmarked funds for vaccines and infectious-disease programmes; supplements, not replaces, traditional aid	J. Michaud & J. Kates (2011), R. Atun *et al*. (2012; 2017)
ESG-aligned private capital	Draws mainstream financial-sector actors into health investment	R. Krech *et al*. (2018)
Climate-linked financing (multilateral funds, levies, adaptive social protection)	Generates health-sector resources while building resilience to climate shocks	J. Borghi *et al*. (2024)
Pandemic-preparedness pooled funds	Finances cross-border health-security functions; requires broader governance and funding base	M. Shahid *et al*. (2024), H. Robertson *et al*. (2024)
Emergency reserve funds and earmarked levies for biological/climate crises	Provides rapid liquidity when climate and pandemic shocks coincide; directly competes with the other instruments above for the same fiscal space	M. Yaghoubi *et al*. (2023), M. Shahid *et al*. (2024)
Domestic "sin" and digital taxes	Expands fiscal space domestically; effectiveness limited by weak administration and informality	F. Mpofu & S. Chilunjika (2026)
Provider-competition reform (Ukraine)	Increases patient choice; distributional effect on equitable access remains open	L. Deshko *et al*. (2020), L. Beztelesna *et al*. (2024)

Source: compiled by the author based on the reviewed literature

Taken together, the Ukrainian evidence points to a system that has become more resilient and more competitive without yet becoming more equal. The 2018 financing reform strengthened aggregate resilience and introduced genuine competition among providers, and this competition held even through the compounding shocks of the pandemic and the full-scale war. What the reform has not resolved is the distributional layer beneath that aggregate resilience: informal payments continue to function as a parallel, regressive charge on households; financial provision remains uneven across regions and facility types; and the same institutional weaknesses – limited enforcement capacity, incomplete regulation of the growing private sector, and thin accountability at the facility level – that constrain transferability elsewhere also constrain whether Ukraine's gains in system-level resilience reach the patients and regions that need them most.

CONCLUSIONS

This review showed that global health economics has moved decisively beyond the narrow question of whether a specific intervention is cost-effective. The dominant current issue was how to finance universal health coverage without transferring financial risk onto households; this is compounded by the need to balance equity against efficiency, to build the fiscal space required for climate adaptation and pandemic preparedness, and to design financing institutions capable of pooling, allocating, and channelling resources effectively across highly heterogeneous settings. In economic terms, the evidence assembled in this review pointed to a structural mismatch between the volume of resources currently mobilised for health and the growth of an increasingly correlated set of demands – universal coverage, climate adaptation, and pandemic preparedness – competing for the same constrained fiscal space; closing this gap requires not proportionally more of the same financing instruments but a deliberate reallocation toward instruments that expand the underlying tax and contribution base, rather than reshuffle a fixed pool of resources among competing priorities. The quantitative evidence reviewed here – approximately 4.5 billion people lacking full access to essential services, roughly USD 8.9 billion mobilised through innovative financing instruments between 2002 and 2015, and an estimated 37% and 9% of total health spending required from low-income and lower-middle-income countries respectively to meet global pandemic-preparedness targets – indicated that the financing gap in global health is substantial and cannot be closed through incremental growth in traditional development assistance alone.

The Ukrainian-authored literature added a domestic dimension to this global pattern. It showed that underfinancing relative to GDP, informal payments functioning as a regressive parallel user-charge system, and a post-2018 reform model built around competition among providers coexist with an explicit policy commitment to universality, equity, and financial protection. This combination makes Ukraine a useful case for testing, at the country level, the same general proposition that emerges from the global literature: the central challenge is not simply how much money flows into a health system, but whether the financing architecture, provider incentives, and institutional capacity are matched to the setting in which they are meant to operate. Future research should prioritise two directions: household-level evidence on the distributional effects of climate-linked and pandemic-preparedness financing instruments, and comparative assessment of whether Ukraine's provider-competition reform improves equitable access or mainly reallocates existing demand.

ACKNOWLEDGEMENTS

None.

FUNDING

None.

CONFLICT OF INTEREST

None.

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Актуальні проблеми глобальної економіки охорони здоров'я: фінансування, справедливість та стійкість (огляд літератури)

Анотація. Метою цього дослідження було узагальнити та критично оцінити сучасні напрямки фінансування охорони здоров'я у світі, визначити основні точки протиріччя між ефективністю та справедливістю, а також проаналізувати, як кліматичні зміни та ризик пандемій вплинули на переорієнтацію політики фінансування. Дослідження ґрунтувалося на наративному узагальненні 42 наукових джерел, опублікованих переважно в період з 2010 по 2026 роки, серед яких – аналітичні звіти, систематичні огляди та емпіричні дослідження, індексовані в провідних бібліографічних базах даних, а також кілька українських праць, присвячених реформі фінансування, неформальним платежам та ефективності системи. Аналіз літератури показав, що приблизно 4,5 мільярда людей досі не мають повного доступу до базових медичних послуг, що реформи, орієнтовані на ефективність, можуть поглибити соціально-економічну нерівність у системах, де домінує приватний сектор, а також що фінансування заходів з підготовки до пандемій є недостатнім і географічно незбалансованим: на Африку припадає близько 70 % загального обсягу фінансування заходів з підготовки, незважаючи на те, що цей регіон несе непропорційно велику частку відповідного ризику. Інноваційні інструменти фінансування, запроваджені у період з 2002 по 2015 рік, дозволили залучити приблизно 8,9 млрд доларів США – це незначна частка загальної допомоги на розвиток у сфері охорони здоров'я, яка спрямовувалася переважно на програми вакцинації та боротьби з інфекційними захворюваннями, а не на зміцнення системи. Фінансування заходів у сфері зміни клімату дедалі частіше розглядається як інструмент фінансування охорони здоров'я, а не суто екологічний інструмент, тоді як країнам з низьким та нижчим середнім рівнем доходу доведеться виділяти приблизно 37 % та 9 % від загальних витрат на охорону здоров'я, щоб досягти глобальних цілей щодо готовності до пандемій за нинішніх моделей фінансування. Українські публікації висвітлюють схожі проблеми: неформальні платежі, недостатнє фінансування відносно ВВП, а також модель фінансування після реформи, яка все ще проходить випробування на здатність поєднувати конкуренцію між постачальниками послуг із рівним доступом. У підсумку, головним викликом для економіки глобального здоров'я є вже не витрати на охорону здоров'я, а те, наскільки архітектура фінансування, інституційна спроможність та механізми управління відповідають умовам, у яких вони функціонують

Ключові слова: загальне медичне охоплення; фінансування охорони здоров'я; компроміс справедливість-ефективність; фінансування пандемічної готовності; кліматичне фінансування; стійкість медичної системи

ЕКОНОМІКА РОЗВИТКУ
Міжнародний економічний журнал

Том 25, № 3
2026

Відповідальний редактор:
Н. Проскурніна

Підписано до друку 01.09.2026
Формат 60*84/8
Ум. друк. арк. 9,7
Наклад 50 прим.

Видавництво: Харківський національний економічний університет імені Семена Кузнеця
61166, пров. Інженерний, 1-А, м. Харків, Україна
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https://ecdev.com.ua/uk

ECONOMICS OF DEVELOPMENT
International Economic Journal

Volume 25, No. 3
2026

Managing Editor:
N. Proskurnina

Signed to the print 01.09.2026
Format 60*84/8
Conventional Printed Sheet 9.7
Circulation 50 copies

Publisher: Simon Kuznets Kharkiv National University of Economics
61166, 1-A Inzhenerny Ln., Kharkiv, Ukraine
E-mail: info@ecdev.com.ua
https://ecdev.com.ua/en