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Digital Technology's Impact on Service Sector Productivity and Modernization

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Abstract

Introduction. The effect of digital technology on productivity of service industry is imperative regarding economic growth of the world economy especially where service industries dominate GDP in developed economies. The paper looks at the aspect of digital transformation in relation to its impact on service productivity in 176 economies between 2009 and 2023 in terms of disparities in income levels, economies of scale perspectives, and structural modernization.

Materials and Methods. In the investigation of the association between service labor productivity and digital technology (as evaluated using the ICT Development Index), we used a cross-nation panel data and fixed-effects regression generalization. Testing of the mechanism involved economies of scale analyses of mediation as well as structural modernization. UNCTAD and the World Bank were used as sources of data regarding 176 economies, and the period was 15 years.

Results. Each unit increase in the ICT Development Index stimulated a 0.43 percent growth in the service labor productivity ($p < 0.01$). The 8.8 percentage productivity growth was attributed to high-income countries than the middle and low incomes nations. The improvement of productivity through economies of scale and structural modernization led to digitalization; however, it had minimal impact in the developing regions because of the mismatched infrastructure and missing integration in the developing areas.

Discussion and Conclusion. In high-income economies, digital technology has a very strong environment in increasing service productivity but in the lower-income contexts, it has less significant effects. The policy implications are that there should be specific investments in digital infrastructure, institutional preparation, and human capital provision to achieve growth on an inclusive basis. There are data availability and heterogeneity of regions. Digital inclusion strategies and the firm-level dynamics should be investigated in the future. This paper contributes to the quantitative data on unevenness in digital transformation around the globe and it guides on how policy makers can utilize it to achieve a sustainable economic growth.

Keywords: digital technology, service industry productivity, cross-national panel data, economies of scale, structural modernization, income-level heterogeneity, digital divide, policy implications

Conflict of interest. The authors declare no conflict of interest.

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Влияние цифровых технологий на производительность и модернизацию сектора услуг

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Аннотация

Введение. Влияние цифровых технологий на производительность в сфере услуг имеет решающее значение для роста мировой экономики, особенно в развитых странах, где сфера услуг доминирует в валовом внутреннем продукте (ВВП). Цель статьи – проанализировать влияние цифровой трансформации на производительность в сфере услуг в 176 странах в период с 2009 по 2023 год с точки зрения различий в уровнях доходов, перспектив экономии от масштаба и структурной модернизации.
Материалы и методы. При исследовании связи между производительностью труда в сфере услуг и цифровыми технологиями, которые оценивались с помощью Индекса развития информационно-коммуникационных технологий (ИКТ), использовались международные панельные данные и обобщение регрессии с фиксированными эффектами. Тестирование механизма включало в себя анализ экономии от масштаба в посредничестве, а также структурной модернизации. Источниками данных послужили материалы Конференции Организации Объединенных Наций по торговле и развитию (ЮНКТАД) и Всемирного банка.
Результаты исследования. Каждое увеличение индекса развития ИКТ стимулировало рост производительности труда в сфере услуг на 0,43 % ($p < 0,01$). При этом в странах с высоким уровнем дохода отмечено увеличение показателя на 8,8 %; повышение производительности за счет экономии и структурной модернизации привело к цифровизации. Однако в развивающихся регионах это оказало минимальное влияние из-за несоответствия инфраструктуры и отсутствия процессов интеграции.
Обсуждение и заключение. В странах с высоким уровнем дохода цифровые технологии создают благоприятную среду для повышения производительности в сфере услуг, но в странах с низким уровнем дохода их влияние менее значимо. Для достижения инклюзивного роста нужно целенаправленно инвестировать в цифровую инфраструктуру, институциональную подготовку и обеспечение человеческого капитала, учитывая региональную специфику. В перспективе необходимо изучить стратегии цифровой инклюзии и динамику в разрезе компаний. Настоящее исследование предоставляет количественные данные о неравномерности цифровой трансформации во всем мире, а также рекомендации по их использованию политиками для достижения устойчивого экономического роста.

Ключевые слова: цифровые технологии, производительность в сфере услуг, межнациональные панельные данные, экономия за счет масштаба, структурная модернизация, неоднородность по уровню доходов, цифровой разрыв, последствия для политики

Конфликт интересов. Авторы заявляют об отсутствии конфликта интересов.

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Introduction. As noted by the World Bank (2023), service sector often means bigger share in present GDP in developed economies. This change in structure underlines the increased relevance of studying the dynamics of productivity in service industry in context of the intensive digital transformation. However, economic growth has continued to slow

down, leading to low productivity issues. The 'middle-income trap' dilemma persists as a contemporary challenge for nations based on Brazil's current situation. Brazil made initial digital transformation moves in 2015 but has experienced inconsistent progress due to the need for continuous policy backing and infrastructure expansion. We conduct this extended research to study digital technology's effects on service productivity for varying economic levels.

Personalization makes it difficult for the service industry to follow the manufacturing industry in standardized production, which can lead to high-cost expansion and impact on economic growth. The improvement of service industry productivity is not only related to the rise and fall of the industry but also to the success or failure of structural transformation and the sustainability of economic growth. Research F. Nucci et al. has pointed out that Brazil's service industry productivity has long been lower than that of the industrial industry, and the productivity gap has not been narrowed [1]. The modernization of the service industry has been relatively slow, and premature deindustrialization is closely related to the lag in productivity in the service sector.

Studies by P. Gandhi[1] and J. Hua et al. [2] have shown that digital technology influences the service business via theoretical mechanisms, fast division of labor, and innovation. Digital technology boosts service industry productivity via structural impact, enabling effect, and economies of scale, shifting it from a "stagnant sector". However, non-standard delivery offers sellers a monopolistic advantage, reducing their motivation to improve efficiency. Standardized production in service industry is difficult to accomplish due to inherent characteristics such as intangibility, non-storability, and heterogeneity, as noted by S. V. Doroshenko and R. I. Vasilyeva[2]. Using economies of scale to boost production efficiency reduces the service industry's technical innovation investment incentives, making it hard for productivity to expand as rapidly as manufacturing.

The National Policy emphasizes R&D investment and human capital optimization in the service sector, which is growing rapidly. The Brazilian Institute of Geography and Statistics (IBGE) addresses this topic. Digital technology boosts service sector productivity by making high-skilled workers more flexible and marketable. Yet, the literature lacks mechanism testing, empirical research on economies of scale, cross-national data, and middle- and low-income economy disparities. The study also lacks a realistic backdrop of great power rivalry in the digital technology revolution and does not analyze how digital technology affects service sector productivity in various countries.

To address these gaps, this research employs cross-nation panel statistics from 2009 to 2023 to check out how digital technology has changed the service industry's productivity, with an emphasis on economy of scale and structural modernization, while situating the findings within the broader context of global digital competition and uneven development trajectories.

Grishina et al. examined annual changes in employment share and relative labor productivity of service industry in typical countries, revealing distinct patterns of sectoral development [3]. Note: 1) Based on data from ten industry sectors from the Groningen

[1] Gandhi P. Digital Technology and CRM Implementation in the Hospital of Delhi and NCR. In: Singh S.N., Mahanta S., Singh Y.J. (eds.) Proceedings of the NIELIT's International Conference on Communication, Electronics and Digital Technology. Singapore; 2023. Pp. 629–640. https://doi.org/10.1007/978-981-99-1699-3_44

[2] Doroshenko S.V., Vasilyeva R.I. Spatial Estimation of Regional Economic Growth Heterogeneity During 2014–2021. *Russian Journal of Regional Studies.* 2024;32(3):484–503. https://doi.org/10.15507/2413-1407.128.032.202403.484-503

Growth and Development Centre (GGDC); 2) The values next to the lines in the figure, such as "1950", represent the years.

Literature Review. *Characteristics of the traditional service industry and constraints on improving its production.* According to M. S. Abdurashidova and M. E. Balbaa[3], features of the conventional service business and its inability to boost production efficiency. N. B. Baker et al. [4] emphasized that in study shows that the conventional service business cannot be preserved and produces non-physical forms. Concurrent consumption and production are common. Customers choose whether the services offered are either diverse or non-standardized. Production and distribution focusing on 14–24-year-old needs. Moreover, L. S. Bjerke-Busch and S. Thorp [5] point out that these qualities, which are mentioned below, make service-sector productivity hard to be increased: First, gradual and labor-saving technical innovation increases productivity; second, the service industry's tradability is decreased and its value is added due to the non-storability feature. As S. C. Chiemeke and O. M. Imafidor [6] argue, trade and specialization bring scale economies. Besides: Material knowledge economy is the main concept of the new service industry along with high-tech and human resources. Additionally, V. Dear et al. [7] suggest that modern, capital-intensive, high-value technology and idea are combined with the business strategy which makes the direction clearer. Productive and life service industries are specializing and developing. X. Fu et al. [8] further note that service sector variety and quality are improving.

Digital technology, reshaping of economies of scale and productivity in the service industry. Increased returns are needed to boost service sector productivity. According to C. Jin et al. [9], scale economies boost returns. Redesigning the service form to be tradable and standard service sector productivity is now driven by economies of scale. Encoding knowledge with digital technology changes services..As emphasized by J. Vazquez et al. [10], digital technology has made service exports more competitive. Though products and transaction qualities restrict its tradability, digital technology may alter that. K. Kosior [11] highlights that non-storability, physical formlessness, and synchronization of conventional services. Thus, conventional services become non-tradable. Servicing knowledge encodes digital technology's basic mechanism.

However, in the opinion of V. Krasnomovets et al.[4], traditional services like music, education, and entertainment have their unique essence. The transfer of knowledge remains restricted because services cannot be stored and require shipping methods which reduce distant trade possibilities. Digital technology binds knowledge into special network platforms and storage media systems that make these services not exchangeable between consumers. As noted by T. Kulinich et al. [12], digital technology also lowers service trade costs. L. Laszig et al.[5] adds that countries' geographical distance affects trade transaction costs. International commerce transportation and communication expenses,

[3] Abdurashidova M.S., Balbaa M.E. Digital Transformation of the Industrial Sector: The Case of Uzbekistan Economy [Электронный ресурс]. In: ICFNDS'22: Proceedings of the 6th International Conference on Future Networks and Distributed Systems. Pp. 130–136. https://doi.org/10.1145/3584202.3584222

[4] Krasnomovets V., Mazniev I., Sarana O., Shulha O., Khomiuk N., Artemchuk L. Operational Management of Service Field Enterprises under the Conditions of Digitalization in the System of Sustainable Development. *Ad Alta-Journal of Interdisciplinary Research.* 2024;14(1):235–239.

[5] Laszig L., Bahr M., Gad G.M., Lomiento G. Effect of Innovation on Productivity in the Construction Industry: A Literature Review. In: Construction Research Congress 2020: Computer Applications. 2020. https://doi.org/10.1061/9780784482865.058

information collecting and transaction monitoring costs, customer assessment and pre- and after-sales service costs, etc. Digital technology reduces service trade expenses, but it also drives conventional service industry firms. L. Laszig et al. argues that digitization is lowering trade thresholds, export transaction settlement and logistics coordination can be automated, and more SME are entering international trade. Endless connection and massive data aggregation and processing optimize.

Traditional service variation occurs because individuals provide directly to consumers, which is determined by scene, environment, and people [13]. A. More et al.[6] note that wide range makes standard services challenging. Standardization through compliance collection, storage, and analysis of big data, models, and algorithms to extract and use standardized indicators and weights to embed service decisions in implementation, and standardized processes to reduce service variance[7]. As suggested by F. Nucci et al. [1], improving digital technology's knowledge encoding facilitates transformation of conventional service products by decreasing reliance on direct human interaction.

Digital Technology, Structural Modernization and Service Industry Productivity. Modernizing the service sector will boost productivity. This procedure changes structural proportions from traditional to contemporary. Modern service business is growing while conventional service industry is shrinking M. V. Tereshina et al. [14]. Productive services are rising while life services are falling. The percentage of services falls. It is the digital technology that is transforming the service business and self-betterment is the main drive for that.

In this context, C. C. Osorio-Gomez et al. [15] argue that traditional service sectors including retail, wholesale, catering, commerce, banking, and planning are not productive. The new technology-fueled service sectors, for example, computer communication, are much more efficient. According to M. Sarabdeen and H. Alofaysan[8], service sector productivity increases. Digital technology modernizes and transforms service businesses. Transformation, for example, the cultural business is an inefficient service industry, but digital technology supports cultural aspects, making cultural goods more diverse and expressive. It boosted cultural industry efficiency. Digital technology boosts service business efficiency without extending its size.

Technological R&D and labor quality supplanted contemporary physical capital in influences on commercial services, digitalization, and intelligence. Improved industrialization and input factor efficiency. For service industry spatial arrangement, industrial clusters no longer use conventional centralized control of the decentralized layout at the macro level has decreased the favorable impact of industrial agglomeration, and the micro level agglomeration model will become the major focus. A decentralized flow model makes more favorable conditions for balanced regional service industry growth, while digital technology has simultaneously enabled creation of new modern services as noted by E. G. Leonidova [16].

[6] More A., Aslekar A. Role of ICT and Fintech in Indian Agriculture. 2022. In: International Conference on Decision Aid Sciences and Applications (DASA). Chiangrai, Thailand; 2022. Pp. 900–904. https://doi.org/10.1109/DASA54658.2022.9765170

[7] Lorincz J. Searching Toolboxes for the Right Solution. Manufacturing Engineering. 2014. Available at: https://jglobal.jst.go.jp/copylink?JGLOBAL_ID=201402206275083541 (accessed 10.02.2025).

[8] Sarabdeen M., Alofaysan H. Investigating the Impact of Digital Transformation on the Labor Market in the Era of Changing Digital Transformation Dynamics in Saudi Arabia. *Economies*. 2023;11(1):12.

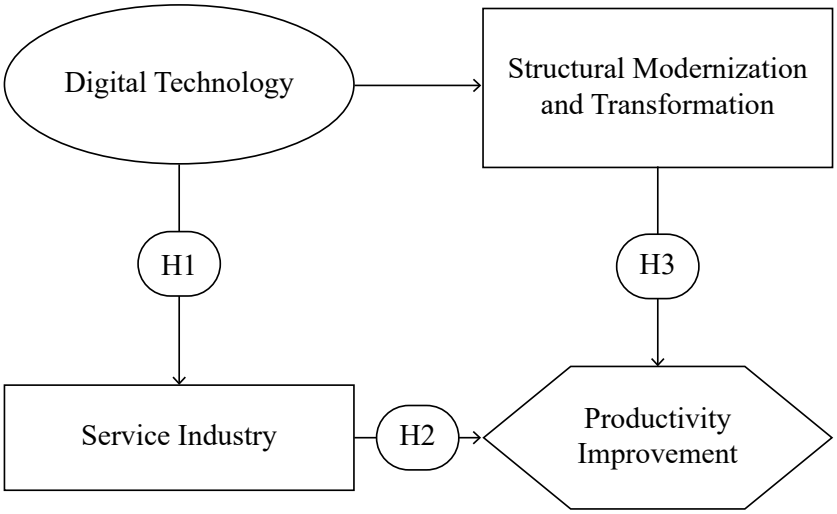
Increasing returns from economies of scale and scope, convenience, and algorithm and network cluster benefits to develop rules encourage the traditional service contemporary transformation of the business. Study analysis indicates digital technology improves service industry performance by establishing two fundamental pathways that involve economies of scale and structural modernization. The mechanisms emerged from combining conceptual models with empirical research studies across high-income and developing countries.

The hypotheses were solidified through an analysis framework from R. M. Baron and D. A. Kenny[9] (1986) which checked for indirect transmission of digital technology effects on service productivity through these two channels. Specifically.

H2: Digital technology can reshape the economies of scale in service industry, thereby improving service industry productivity.

H3:Digital technology promotes the modernization and transformation of the service industry structure, thereby improving productivity of service industry.

The conceptual model in Fig. 1 presents the way digital technology directly affects service productivity but does so through the two mediators. Mechanism Test Results conducts empirical tests based on panel regression models containing interaction terms alongside estimations of mediation effects to confirm the analysis.



F i g. 1. Hypothesis Framework Diagram[10]

Materials and Methods. *Econometric model setting. Baseline Model Setting.* To check digital technology impact on the productivity of the service industry. In terms of quantitative empirical research, we use cross-national panel data to analyze Its continuous data characteristics and consider the possible differences between different countries Some unobservable individual characteristics may lead to the omission of certain variables.

[9] Baron R.M., Kenny D.A. The Moderator–Mediator Variable Distinction in Social Psychological Research: Conceptual, Strategic, and Statistical Considerations. *Journal of Personality and Social Psychology.* 1986;51(6):1173–1182.

[10] Source: Developed by Author.

The endogeneity problem caused by the introduction of the individual effect model is based on this. Hausman test was performed to determine the estimation efficiency of the random effect model and fixed effect model. The test results significantly rejected the null hypothesis, indicating that individual effects are related to explanatory variables, and fixed effects models.

The standard panel data econometric frameworks that can be used to trace cross-country productivity are utilized in our baseline model (e.g. [9; 10]). It is stated as follows (Equation 1):

$$\text{Ser\_LP}_{it} = \beta_0 + \beta_1 \text{Digital}_{it} + \gamma Z_{it} + \mu_i + \eta_t + \in_{it} \ , \quad (1)$$

where Ser_LP_{it} – signifies labor productivity of service sector in economy i in year t. It is calculated as the logarithm of real value added per worker in service industry; β_0 – is intercept or constant term; β_1 – is the coefficient of primary interest; Digital_{it} – digital technology development level in economy i in year t, measured by the ICT Development Index from UNCTAD; γ – is a vector of coefficients corresponding to the control variables; Z_{it} – is a vector of control variables together with population aging, human capital, infrastructure, natural resources, energy use, population size, GDP per capita, and urbanization rate; μ_i – captures unobserved time-invariant country-specific effects; η_t – controls for common time trends; $\in_{it}$ – is the idiosyncratic error term.

This model is estimated using fixed effects to account for potential heterogeneity across countries.

Mechanism Testing Model Setting. Study utilized a mediation analysis framework to test mutual mediation of the economies of scale and structural modernization by estimating equations using fixed-effects regression models. Interaction effects are also seized to gauge conditional effects. There was no generalized method of moments (GMM) applied given that the time horizon (T = 15) is relatively short and that there are no major endogeneity concerns which cannot be overcome by introduction of lagged variables.

No.i economies t years of digital technology; is intercept – baseline level of service labor productivity; χ_1 is total effect of digital technology (Digitalit) on service productivity (Ser_LPit), before controlling for the mediator; χ_j is coefficients for control variables (Z); Z is control variables set; μ_i is the individual fixed effect; η_t is the year fixed; δ_0 is intercept in mediation model; δ_1 is direct effect in mediation model; δ_2 is mediator effect coefficient; δ_j is control variable coefficients in mediation model; $\in_{it}$ is a random disturbance term. Due to data availability, the percentage of medium and high-tech service exports is used. The proportion of total service exports indicates the degree of structural modernization of the service industry in:

$$\text{Ser\_LP}_{it} = \chi_0 + \chi_1 \text{Digital}_{it} + \chi_j Z + \mu_i + \eta_t + \in_{it}, \quad (2)$$

$$\text{M}_{it}^k = \beta_0 + \beta_1 \text{Digital}_{it} + \beta_j Z + \mu_i + \eta_t + \in_{it}, \quad (3)$$

$$\text{Ser\_LP}_{it} = \delta_0 + \delta_1 \text{Digital}_{it} + \delta_2 \text{M}_{it}^k + \delta_j Z + \mu_i + \eta_t + \in_{it} \ . \quad (4)$$

In formulas (2) to (4): $\text{M}_{it}^k r$ represents the mediating variable, $k = 1,2$; $\text{M}_{it}^1 r$ represents economies of scale); represents structural modernization (Str_Upit).

Variable Description. Explanatory variables. The Digital technology development level uses ICT Development Index (IDI) of (UNCTAD) as its measurement tool. The IDI serves as a standardization method which combines various measures regarding ICT infrastructure usage and skills in different countries. This measurement produces standardized values between 0 and 100 which demonstrate digitalization intensity. Research based on various countries utilizes this index because of its proven reliability together with its comprehensive nature.

Explained variables. Service industry productivity (Ser_LP): According to general practice, it is expressed using labor productivity of service industry. Ratio of employment in service industry to the number of employees is expressed in logarithm. All amounts are in 2015 constant US dollars, aligned with the World Bank's latest GDP rebasing. A fixed base year enables comparability across time and across nations. The choice of 2015 reflects data availability rather than obsolescence.

Mechanism variables. Economies of scale: expressed as the proportion of service trade to GDP. The above analysis points out that the mechanisms of economies of scale include: The level of trade and standardization has increased, but standardization of the service industry is difficult to achieve as in equation 5.

$$\textit{Exports of medium and high-tech services} = \textit{Exports of ICT services} + \textit{Exports of financial and insurance services}. \quad (5)$$

Control variables. Population aging (Aging): signified by population aged 65 and above; human capital (HC), infrastructure (Infstr), natural resources (Natural), energy level (Energy): represented by the human capital index, infrastructure index, natural resources index, and energy index provided by the NCTAD database respectively; population size (pop): represented by the logarithm of the population size; GDP per capita (per GDP): 2015 constant US dollars directly provided by the World Bank; urbanization rate (urban): signified by urban population.

Data Description. A cross-national panel dataset used for research extends from 2009 to 2023 and includes 176 economies. Applications of this method result in 2,640 possible observations when multiplying 176 countries with 15 years span. Different variable indicators result in varying actual observation numbers which are shown in Table 1. The data contains missing values because (1) individual countries report different indicators over time, (2) World Bank data differs from UNCTAD data, (3) classification changes in service trade categories produce inconsistent reporting practices and (4) specific indicators such as high-tech service exports are restricted to select countries during specific time periods. All control variables (e.g. human capital index, natural resources index) were sourced in the UNCTAD database (2023) and the World Bank (2023). Equally, the ICT Development Index (IDI) was obtained through UNCTAD Digital Economy Tools. All analysis data remains intact because the researchers avoid replacing any missing values to sustain the accuracy of their empirical findings.

T a b l e 1. **Descriptive statistics of variables**

Variable	Sample size / mean		Standard Deviation	Minimum	Maximum
1	2	3	4	5	6
Productivity in the service sector	2239	9.604	1.095	7.017	12.361
Digital Technology Development Level	2262	43.621	20.431	2.157	97.032
Aging population	2262	8.338	6.114	0.171	29.793
Human capital	2262	44.461	18.371	7.745	100
Transport infrastructure	2262	40.021	17.591	1.032	92.221

End of the table 1

1	2	3	4	5	6
Natural Resources Index	2262	39.991	13.691	2.658	85.261
Energy Index	2262	52.671	21.621	1.872	99.632
Population size	2262	15.971	1.792	11.561	21.063
GDP per capita	2253	8.577	1.401	5.572	11.591
Urbanization rate	2262	57.671	22.851	10.381	100
Economies of scale	2117	24.252	29.482	2.005	316.31
Structural modernization	1967	15.021	13.693	0.08	93.172

Note. Sample size discrepancy is because of differences in availability of data. Missing values result from incomplete reporting, limited country-year coverage, and some data limitations.

Results. *Benchmark Results Analysis.* The fixed effect model was used for regression analysis, and results are revealed in Table 2. As shown in the model without control variables, digital technology has significant impact on service sector productivity in high-income economies, the level of trade in services is used to describe Economies of scale. Structural modernization (Str_M) the initial consideration is to use added value of medium and high-tech services proportion to the added value of the service industry. Obtain data on the added value of medium and high-tech service industries in various countries around the world, considering estimated coefficient of business productivity is positive and passes the 1 % significance level test; after gradually adding control variables, R2 the estimated coefficient of digital technology on service industry productivity is still positive and the test passed the 1 % significance level test. This demonstrates how digital technology growth has encouraged the service sector's increased productivity.

T a b l e 2. **Variable benchmark regression results**

Variable	Main effect only	Demographics	Infrastructure and Resources	Energy and Population	Economic Controls
Ser_LP					
	Benchmark Model	Join Aging and HC	Join infstr and Natural	Add Energy and Pop	Join pergdp and urban
1	2	3	4	5	6
Digital	0.0105***	0.0051***	0.0053***	0.0059***	0.0028***
	– 0.0008	– 0.0005	– 0.0005	– 0.0006	– 0.0006
Aging		0.0125***	0.0161***	0.0067**	0.0067**
		– 0.0032	– 0.0033	– 0.0035	– 0.0032
HC		0.0045***	0.0045***	0.0098***	0.0078***
		– 0.0014	– 0.0014	– 0.0014	– 0.0013
Infstr			0.0032***	0.0022***	0.0014***
			– 0.0005	– 0.0005	– 0.0005

End of the table 2

1	2	3	4	5	6
Natural			– 0.0022*	– 0.0018*	0.0008

Notes. 1) The values are robust standard errors; 2) *, ** and *** indicate significance at the 10, 5 and 1 % levels, respectively. The same is below. The term "Benchmark Model" denotes the regression model which contains only the main explanatory variable (Digital), and its further columns add blocks of control variables progressively; 3) Ser_LP – Service Labor Productivity, Digital – Digital Technology Development Level, Aging – Population Aging, HC – Human Capital, Infstr – Infrastructure, Natural – Natural Resources.

Robustness Test. Changing Explanatory Variables. As a robustness check, the ICT Development Index has been replaced by the Internet Development Index, which is a measure of digital development. The latter has been obtained by taking the geometric mean of normalized values for mobile cellular subscriptions, fixed broadband subscriptions, and Internet users per 100 people (in accordance [1]). This final index has been rescaled to be between 0 and 100 (in line with the aforementioned data).

Multiple indicators which examine different dimensions of digital infrastructure coverage serve as the basis for this assessment. The geometric mean of normalized component values builds a composite index through a method that prevents individual indicators from disproportionately influencing the result. The variables undergo min-max normalization to reach standardization before the aggregation process. The obtained index spreads from 0 to 100 points and identifies countries based on their Internet penetration and digital infrastructure advancement levels.

This Internet Development Index is then used as the key explanatory variable in a re-estimated version of the baseline model. Table 3 presents the overall regression results using this revised specification. While the table does not break down results by individual components, sensitivity checks confirmed that all three indicators individually yield consistent signs and significance levels, reinforcing the robustness of the findings.

T a b l e 3. **Robustness test results of benchmark regression analysis**

Ser_LP				
Variable	Changing explanatory variables		Instrumental Variables	
	No control variable	Add Control variable	No control variable	Add Control Variable
1	2	3	4	5
Digital	0.0043***	0.0011***	0.0088***	0.0042***
	– 0.0006	– 0.0005	– 0.0005	– 0.0008
Aging		– 0.0008		– 0.0008
		– 0.0033		– 0.0035
HC		0.0078***		0.0073***
		– 0.0012		– 0.0014
Infstr		0.0014***		0.0016***
		– 0.0005		– 0.0006
Natural		0.0011		0.0009
		– 0.0011		– 0.0011
Energy		– 0.0031***		– 0.0035***

End of the table 3

1	2	3	4	5
Energy		– 0.0009		– 0.0011
Pop			– 0.0955**	– 0.2019***
		– 0.041		– 0.0467
Pergdp			0.5963***	0.5050***
		– 0.0235		– 0.0276
Urban		0.0011		0.0001
		– 0.0018		– 0.0018
Constant	9.4736***		5.6451***	
	– 0.0141	– 0.6718		
N /	2131	2130	2231	2231
R2	0.191	0.4425	0.1948	0.3847

Notes. 1) The research centers on the Internet Development Index but supplementary breakdowns with individual indicators produce equivalent findings; 2) Energy – Energy Use, Pop – Population Size, Pergdp – GDP per Capita, Urban – Urbanization Rate, N – (Number of Observations), R2 – Coefficient of Determination.

Instrumental variable method. There may be causal issues in empirical analysis, that is, service. The more productivity of the industry, the better digital technology development of economy will be. To address potential endogeneity issue, study introduces a lagged value of the digital technology level as an instrumental variable. Study employed a lagged version of digital technology (12 months back) as an instrumental variable to manage probable endogeneity. In line with J. M. Wooldridge[11], this strategy implies that the previous states of digital technology are inter-related with recent efficiency yet not affected by shocks occurring at the same time. In order to select this instrumental variable, it must be uncorrelated with the explained variable. Table 3: Test results in the absence of controls, digital technology has a positive impact on service productivity at 1 %. Controls established after implementation have no effect on the digital technology impact. There are some controls that have a negative impact on productivity, reducing the service sector productivity.

The test results are revealed in Table 3. In test model without control variables, the estimated impact of digital technology on service industry production efficiency. Estimated coefficient is positive and passes 1 % significance level test; after adding control variables, the estimated coefficient is still positive and passes the 1 % significance level test. This shows that the development of digital technology has promoted the service. The improvement in industry productivity is consistent with the benchmark results.

Mechanism Test Results. Economies of scale. Table 4 shows the test results on the intermediary effect of scale economy. Among them, the estimated coefficient of digital technology on the productivity of the service industry is positive and significant, that is, the total effect of digital technology on the productivity of the service industry is positive; The estimated coefficient of digital technology on economies of

[11] Wooldridge J.M. Econometric Analysis of Cross Section and Panel Data. The MIT Press Cambridge. Available at: https://doc1.bibliothek.li/aca/FLMF024129.pdf (accessed 10.02.2025).

scale is positive and significant. Technology can promote the expansion of economies of scale. In addition, economies of scale on consensus. The estimated coefficient on service sector productivity is positive and is at the 1 % level. The mediating variable has service industry productivity impact; and at this time, the number estimated coefficient of technology on service industry productivity is still positive and significant at the 1 % level, after controlling for mediating effect, digital technology has a significant. The direct effect of technology on service industry productivity is positive. This shows that there is a mediating effect based on economies of scale, and it is a partial mediating effect.

T a b l e 4. **Results of test on mediating effect of economies of scale**

Variable	Total Effect	Ser_LP	Scale
		Join Scale	
Digital	0.0017***	0.0035***	0.1427**
	– 0.0005	– 0.0006	– 0.0579
Scale		0.0008***	
		– 0.0003	
Aging	0.0027	0.0049	0.3224
	– 0.0033	– 0.003	– 0.2691
HC	0.0077***	0.0045***	0.0305
	– 0.0014	– 0.0013	– 0.1106
Infstr	0.0015***	0.0002	0.0172
	– 0.0006	– 0.0006	– 0.0421
Natural	0.0009	– 0.0001	0.0116
	– 0.0011	– 0.0008	– 0.0859
Energy	– 0.0032***	– 0.0003	– 0.7822***
	– 0.0011	– 0.0008	– 0.0803
Pop	– 0.1406***	– 0.2479***	0.7306
	– 0.0446	– 0.0425	– 3.8326
Pergdp	0.5413***	0.4149***	15.4806***
	– 0.0259	– 0.0282	– 2.5305
Urban	0.0013	0.0006	– 0.3787**
	– 0.0019	– 0.0018	– 0.1504
Constant	6.7622***	9.5729***	– 69.0894
	– 0.7468	– 0.7361	– 66.6828
N/	2238	2098	2098
R2	0.3877	0.3995	0.0715

Note. Scale – Economies of Scale.

Structural modernization effect. Structural modernization effect here points to the mechanism through which digital technologies make it easier for the economic activity to move from traditional service sectors (for example, retail, hospitality) to the modern,

high-value services (e.g., software, fintech) and, traditionally, overall productivity will be improved. Table 5 displays test findings on mediating influence of structural upgrading. Within that group, the predicted coefficient of digital technology is 1 % level significant. The overall impact of digital technology on the productivity of service business is beneficial. The ratio of high-tech service exports to total service exports is used as a metric to gauge the performance of the service sector. The service sector is being structurally modernized, with digital technology being used as a mediating variable. It is a crucial need for achieving continuous economic development by implementing structural changes.

T a b l e 5. **Test results of the transmission mechanism of structural modernization effect**

Variable	Total effect test	Ser_LP	Str_M
		Join Str_M	
Digital	0.0019***	0.0035***	0.0876*
	– 0.0007	– 0.0008	– 0.0519
Str_M		0.0016***	
		– 0.0004	
Aging	0.0029	0.0051*	1.5954***
	– 0.0033	– 0.0031	– 0.2361
HC	0.0079***	0.0037***	0.2315**
	– 0.0014	– 0.0014	– 0.0997
Infstr	0.0015***	0.0003	– 0.1021***
	– 0.0006	– 0.0006	– 0.0375
Natural	0.0009	– 0.0005	– 0.0634
	– 0.0011	– 0.0011	– 0.0767
Energy	– 0.0032***	– 0.0009	0.1182
	– 0.0011	– 0.0008	– 0.0721
Pop	– 0.1406***	– 0.1926***	– 6.5665*
	– 0.0446	– 0.0441	– 3.4711
Pergdp	0.5413***	0.4161***	– 14.1908***
	– 0.0259	– 0.0302	– 2.3648
Urban	0.0013	– 0.0008	0.0002
	– 0.0019	– 0.0018	– 0.1348
Constant	6.7622***	8.8596***	214.3808***
	– 0.7468	– 0.7661	– 60.4256
N/	2238	1953	1963
R2	0.3877	0.3868	0.0844

Escaping the “middle-income trap” is of utmost importance for economies. Countries are categorized by the World Bank's GNI per capita. Low-income economies in FY2024 have a GNI of $1,135 or below, middle-income $1,136 to $13,845, and high-income $13,846 or above. The findings are shown in Table 6. Within the high-income economy category, digital technology has a substantial influence on the output of the service sector. The predicted coefficient of service sector productivity

is positively correlated and statistically significant at the 10 % level. In middle- and low-income nations, digital technology has a considerable influence on service industry productivity. The computed coefficient is associated with the structural modernization of the service sector at the 10 % level, indicating that digital technology may facilitate this process. The calculated coefficient is positive, but, it does not reach statistical significance. This suggests that in high-income countries, digital technology plays a significant role in advancing the service sector in both middle-income and low-middle-income economies.

T a b l e 6. **Results of benchmark regression of variables based on economies of different income types**

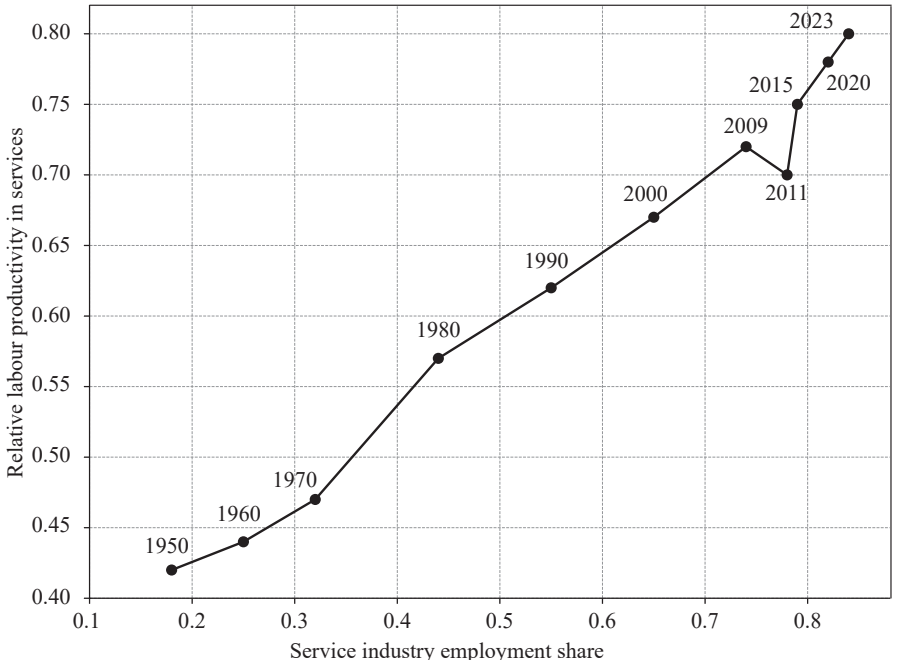
Ser_LP		
Variable	High-income economies	Low- and middle-income economies
Digital	0.0018*	0.0009
	– 0.0012	– 0.0009
Aging	– 0.0109***	0.0032
	– 0.0038	– 0.0057
HC	0.0039**	0.0103***
	– 0.0017	– 0.0019
Infstr	– 0.0017**	0.0019***
	– 0.0009	– 0.0007
Natural	– 0.0043**	0.0014
	– 0.0022	– 0.0013
Energy	0.0019	– 0.0027**
	– 0.0019	– 0.0012
Pop	0.3179***	– 0.2705***
	– 0.0657	– 0.0576
Pergdp	0.5072***	0.603 2***
	– 0.0526	– 0.0308
Urban	0.0036	0.0022
	– 0.0036	– 0.0024
Constant	0.2909	8.1393***
	– 1.2325	– 0.9515
N /	642	1597
R2	0.4459	0.4139

Note. Income group uses the World Bank Atlas method (2024). High-income: GNI per capita ≥ $13,846; middle/low-income: GNI per capita < $13,846.

The impact of productivity gains varies across different economies. In high-income economies, the estimated coefficient on service industry productivity is significant at 1 % level. This implies that structural modernization has a positive effect on service industry productivity, even after accounting for the influence of digital technology. Digital technology significantly enhances service sector efficiency in the service industry, indicating that these economies Currently, digital technology

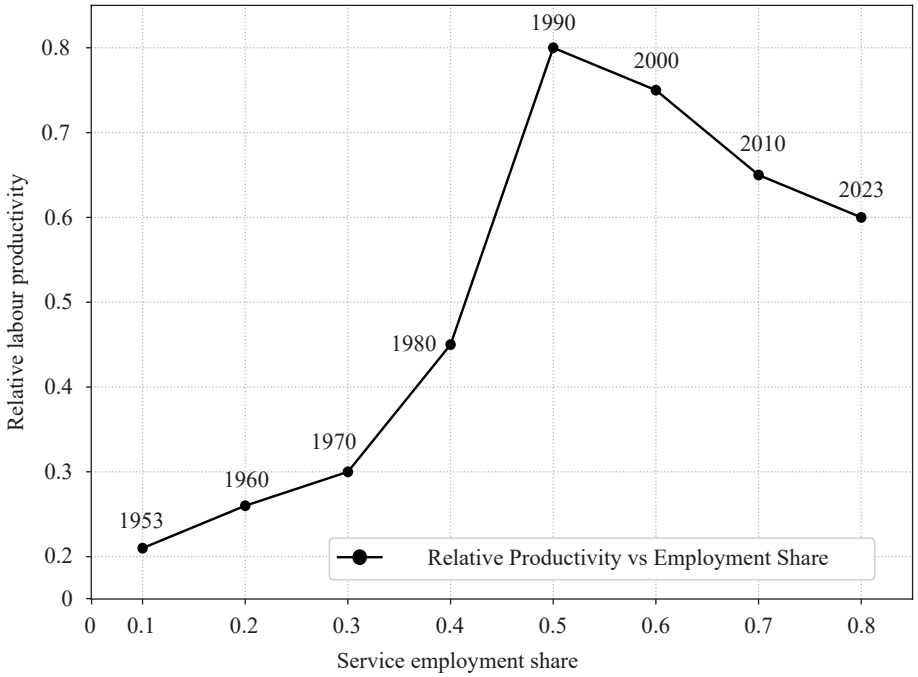
has a favorable influence on the productivity of the service business via the mediating variable. Efficient utilization of digital technology improves productivity in service sector and contributes to economic progress. The estimated coefficient of the approach remains highly positive. This demonstrates the existence of a mediating impact of structural modernization is also a partially mediating effect. To summarize, the advancement of digital technology enhances the productivity of the service business. The transmission mechanism is established by the use of economies of scale and structural modernization.

Comparison of different types of economies. Desirable service industry productivity measurements lead to structural changes within industrial systems. Fig. 2 (UK) and Fig. 3 (Japan) and Fig. 4 (Argentina) depict yearly modifications in service industry employment ratios along with staff productivity in relation to other sectors within the selected nations. These statistical data present various patterns of service sector development based on country classification. Japan together with the UK shows productive service sector improvement and increasing employment rates but Argentina experiences no such growth while its service industry employs more people. Structural transformation along with digital technology adoption offers a greater advantage to countries with higher economic status compared to nations with lower profits.

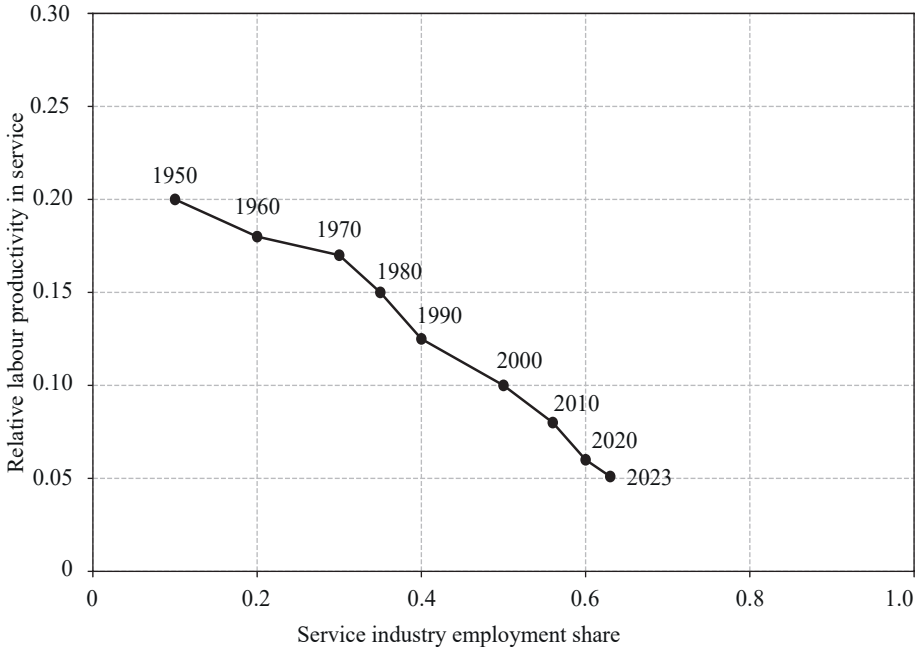


F i g. 2. Frontier Country: UK[12]

[12] Figures 2–4 are taken from the Groningen Growth and Development Centre (GGDC). Available at: https://www.rug.nl/ggdc/?lang=en (accessed 10.02.2025).



F i g. 3. Successful countries: Japan



F i g. 4. Catching up with failed countries: Argentina

Table 6 confirms that digital technology creates greater service productivity impacts in economies with higher incomes as comparison to those with middle- and low-incomes. Technology infrastructure alongside institutional capacity and market maturity seem to

explain why some countries exhibit differences in their digital transformation capabilities to break free from the middle-income trap.

Discussion and Conclusions. This article examines the impact of digital technologies on service productivity in 176 economies from 2009 to 2023. We identify that digitalization boosts productivity in high-income economies via economies of scale and modernization. Middle- and low-income economies have weaker, often insignificant impacts, implying a need for complementary investments in infrastructure and human capital.

Study has significant policy implications in our results. High-income countries must employ digital technologies for better services and innovation. Low- and middle-income economies should focus on digital inclusion, invest in R&D and education, and provide room for digital entrepreneurship. The Brazilian example in 2015 exposes the initial digital reform efforts, but its uneven advancement underscores the need for strategic planning and institutional readiness to accomplish effective digital transformation.

This research uses fixed effects models and investigates the mediating effects to examine the numerical influence of technology on the productivity of the service sector and the identification of operational processes, namely digital technology. Enhanced productivity in the service sector via substantial improvements in economies of scale and structural modernization. Digital technology usage serves to enhance efficiency of the service sector, namely by redefining economies of scale and facilitating structural modernization. Digital technology converts information into a coded format and alters the exchangeable format of services. The aim is to improve service consistency and minimize variations, establish standardized service delivery, and create an environment conducive to attaining economies of scale. Simultaneously, the advancement of digital technology allows the service industry to enhance its value and empower itself through digital means. Contemporary advancements assist firms in delivering service content of superior grade. Comparative empirical research from nations with varying incomes reveals that digital technology has a substantial positive effect on service sector productivity in high-income economies, but its influence on service productivity in low-income economies is not significant. Based on the above, policy implications are drawn.

(1) A vigorous development of digital technology contributes to advancement of service industry productivity. Brazil is difficulty of “middle-income trap” by creating the way for the service sector to become more productive and also by changing the growth effect of structural reform. The road toward this is by the entry of a digital service market that is open, innovative, and collaborative. This can be achieved by promoting digital technology innovation, improving supervision, creating a favorable environment for digital technology services, and providing unrestricted access to digital technology and resources. Additionally, Brazil should actively pursue the advancement of cutting-edge digital technologies like 6G and AI, integrating productive services with advanced manufacturing and emerging industries. This will enable the transformation of services into high-end offerings with significant technological value and increased economic worth, contributing to Brazil's service industry structure's continuous improvement.

(2) It is important to consider the implications of digital technology for economies of scale and structural modernization in service sector. Digital technology greatly affects efficiency in the service sector through economies of scale and structural changes. It alters service products through knowledge capture, creating trade and economies of

scale centered around standards. Furthermore, it is a key driver in the modernization of conventional services. In order to fully exploit the digital technology's zero additional costs of production advantage, it is of utmost importance to energize its penetration into the service industry, ensure the integration of service product supply, hasten the digital transformation, and prompt businesses' digital transformation skills development. This will serve to enhance the service sector's digital transformation ecology and service quality.

(3) Multifaceted integration of digital technology and service sector should be promoted to improve productivity and address challenges such as intangibility, non-storability, and heterogeneity in service delivery. The immediate value of digital technology in the service sector is limited, and its influence on productivity needs to be further extended. In order to solve intangibility, non-storability, and heterogeneity problems, it is necessary to explore new integrated application scenarios, enrich online service supply, and meet offline demands while using the positive impacts of digital technology.

(4) Increasing adoption of digital technology in service sector improves global competitiveness of service trade. The digital divide exists between low- and middle-income countries and high-income economies, with digital technology development not significantly impacting the service sector. Low- and middle-income economies should focus on digitalization opportunities, establish consortiums, accelerate digital momentum for service trade, strengthen international exchanges, and integrate digital technology into production and trade fields.

This work illustrates that digital technology enhances the productivity of services in high-income economies through scale and modernization. C. Jin et al. [9] affirm that digital transformation enhances the productivity of services in China through standardization as well as cost reduction. X. Fu et al. [8] assert that digital innovations in multinationals induce structural change in emerging economies.

Study conclusion that digital technology has limited effects in low- and middle-income nations was echoed by T. Kulinich et al. [12], as these authors observed that unbalanced digital infrastructure affects the diffusion of technology in these nations. V. Nucci et al. [1] also demonstrated that digital adoption influences the productivity of firms differently, based on institutional preparedness and market closure.

This study confirms J. Vazquez et al. [10], which finds that digital services enhance productivity and trade. Poor performance of low-income countries highlights importance of investing in human capital and infrastructure, as emphasized by S. C. Chiemeke and O. M. Imafidor [6].

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