

High-Tech Exports and the Future of Pakistan's Service Industry: Examining the Role of Technology Investment, Digital Literacy, and ICT Exports in Driving Sectoral Growth

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Abstract

In the contemporary digital era, the growth and competitiveness of service sectors are increasingly driven by technological advancement, human capital development, and global connectivity. For Pakistan, where the service sector represents a substantial proportion of the national economy, identifying the determinants of sectoral expansion is critical for sustainable economic development. This study investigates the effects of technology investment, digital literacy, and ICT service exports on Pakistan's service sector growth over the period 2000–2024. Employing a Robust Least Squares regression framework, the analysis incorporates Research and Development (R&D) expenditure, High-technology Exports (HTE), Literacy Rate (LR), and ICT Service Exports (ICT) as explanatory variables. Empirical findings indicate that R&D investment, literacy rate, and ICT service exports exert a significant and positive influence on SVA, highlighting the pivotal role of human capital and digital innovation. Conversely, HTE exhibits a negative impact, signaling its limited current contribution to sectoral growth. Anchored in Endogenous Growth and Human Capital theories, the study underscores the necessity of strengthening digital literacy and R&D capacity to enhance Pakistan's service sector performance, fostering alignment with the Sustainable Development Goals (SDGs) and supporting broader digital economy objectives.

Keywords: Service Sector Growth; Digital Literacy; ICT Service Exports; Human Capital; Research and Development; Pakistan Economy.

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1. Introduction

The global economy is undergoing a profound digital transformation, reshaping economic development and sustainability efforts. Digital technologies and ICT adoption are driving economic growth, particularly in emerging economies, while also addressing global challenges like climate change and inequality (Bayumi et al., 2024; Abbas & Zaman, 2024). This transformation aligns closely with several UN Sustainable Development Goals (SDGs), especially SDGs 8, 9, and 17 (Strilchuk et al., 2024). Digitalization catalyzes sustainable development across various sectors, including education, health, and e-commerce (Bayumi et al., 2024). However, persistent digital divides and infrastructure gaps remain significant challenges (Bayumi et al., 2024; Strilchuk et al., 2024). To maximize the benefits of digital transformation, countries must focus on developing digital skills, supporting business digitalization, promoting e-commerce, and enhancing digital literacy (Strilchuk et al., 2024; Abed et al., 2024). These efforts can contribute to achieving multiple SDGs and foster inclusive economic growth in the digital era (Strilchuk et al., 2024; Abbas & Zaman, 2024).

Digital literacy and education are crucial for achieving the UN Sustainable Development Goals (SDGs) and fostering inclusive growth in emerging economies. Improving digital literacy can accelerate progress towards SDGs 1, 4, and 10 by enhancing quality education, reducing poverty, and decreasing inequality (Shafira et al., 2024). Digitalisation significantly contributes to economic growth and poverty reduction in emerging economies (Abbas & Zaman, 2024). However, digital exclusion persists, particularly in countries like Pakistan compared to India and Bangladesh, hindering equal opportunities and social inclusion (Rafiq, 2023). In India, digital education is seen as a catalyst for socio-economic empowerment within the Atmanirbhar Bharat framework, promoting skill development, entrepreneurship, and inclusive growth (Lata, 2024). To maximize the benefits of digital literacy and education, comprehensive policies ensuring equitable access to technology and relevant educational programs are essential (Shafira et al., 2024).

The service sector plays a crucial role in Pakistan's economy, but its potential remains underutilized (Kamal et al., 2023). While the sector shows promise in digital technology and innovation, it faces challenges such as low digital literacy and limited foreign investment (Shah et al., 2023). Addressing these issues is essential for achieving Sustainable Development Goals (SDGs) 8 and 9, which focus on economic growth, infrastructure, and innovation (Subramony & Rosenbaum, 2023). To improve the service sector's contribution, Pakistan should invest in digital capabilities, orientation, and transformation to enhance firm performance and innovation (Shah et al., 2023). Additionally, policymakers should prioritize tackling the digital divide, ensuring digital equality, and increasing funding for research and development initiatives (Singh & Ru, 2023). Balancing technology adoption with labor-intensive development could help create more sustainable employment opportunities in Pakistan's growing service sector (Kamal et al., 2023).

Recent studies highlight Pakistan's efforts to enhance economic competitiveness through digital innovation and skill development. Research emphasizes the shift from globalization to globalisation as a strategy for sustainable growth in Pakistani industries (Ather et al., 2024). The export of human capital, particularly from regions like Khyber Pakhtunkhwa, is explored using game theory, revealing the importance of addressing informational asymmetries and aligning education with global market demands (Shah & Shah, 2024). In the ICT sector, digital capabilities, orientation, and transformation positively impact firm performance through digital innovation (Shah et al., 2023). However, Pakistan's vocational and technical education system faces challenges such as outdated curricula and

weak industry-academia collaboration. Recommendations include investing in digital infrastructure, fostering public-private partnerships, and promoting gender-inclusive strategies to align with Industry 4.0 and Sustainable Development Goals 4 and 8 (Ali et al., 2024).

1.1. Research Problem

Pakistan's service sector, despite its significant contribution to GDP, struggles to achieve sustained growth due to low technology investment, limited digital literacy, and underdeveloped high-tech exports. While global and regional economies have leveraged AI, R&D, and ICT services to enhance service sector performance, Pakistan lags behind. This research aims to investigate how investments in technology, digital skills, and ICT exports can drive value addition and foster sustainable growth in Pakistan's service industry.

1.2. Research Questions

The study has the following research questions, i.e.,

RQ1: How does Research and Development expenditure influence Services Value Added in Pakistan, and to what extent is this relationship moderated by digital literacy?

This question examines how R&D investment drives service sector growth and whether digital literacy enhances this effect. Higher R&D spending can boost innovation in services like IT, but its impact may depend on a digitally literate workforce. Khan et al. (2023) note that R&D fosters service sector growth in developing nations, yet low literacy limits outcomes. This question helps identify how Pakistan can maximize R&D benefits through education. It informs policies for technology-driven growth.

RQ2: How do High-Technology Exports and ICT Service Exports influence Services Value Added in Pakistan?

This question explores how high-tech exports and ICT service exports together drive service sector growth. High-tech exports reflect advanced manufacturing, while ICT exports capture digital service trade. Rehman and Ali (2024) show ICT exports boost service sectors in emerging economies by joining global markets. This question assesses their combined effect in Pakistan. It guides strategies to strengthen tech exports.

RQ3: Does the adult literacy rate mediate the relationship between ICT Service Exports and Services Value Added in Pakistan?

This question investigates if literacy mediates the impact of ICT service exports on service sector growth. A literate workforce supports ICT service scalability. Siddiqui et al. (2025) find literacy enhances ICT-driven growth in South Asia. In Pakistan, low literacy may limit ICT benefits. This question highlights education's role in boosting service exports.

1.3 Objectives of the Study

The following are the objectives of the study, i.e.,

- I. To examine the impact of Research and Development expenditure, high-technology exports, and ICT service exports on Pakistan's services value added.
- II. To assess the moderating role of digital literacy in strengthening the relationship between R&D spending and services sector growth.
- III. To evaluate the mediating effect of adult literacy rate in the relationship between ICT service exports and services value added in Pakistan.

1.4. Significance of the Study

The significance of this study lies in its exploration of how technology investment, digital literacy, and ICT exports can drive Pakistan's service sector growth, a critical component of its GDP. By analyzing these factors, the research addresses a gap in understanding how Pakistan

can leverage high-tech exports and digital capabilities to enhance economic development. It provides actionable insights for policymakers to prioritize R&D, education, and ICT infrastructure. Recent studies, like Ahmed et al. (2024), emphasize that technology-driven service sectors are vital for sustainable growth in developing economies. This study is timely, as Pakistan aims to strengthen its position in global digital markets. It will guide strategies to boost competitiveness and economic resilience.

2. Literature Review

2.1 AI and ICT Policy Frameworks in Pakistan

Hussain and Rizwan (2024) propose a strategic industrial policy for advancing artificial intelligence (AI) in Pakistan to enhance economic resilience and technological sovereignty. Using qualitative analysis and policy synthesis, they conceptualize AI as a multi-layered ecosystem (digital infrastructure, core computing, development platforms, AI-driven services) and highlight Pakistan's overreliance on AI services (Layer 4) and limited foundational innovation, posing risks to national security and economic autonomy. They emphasize AI's potential to boost productivity, attract FDI, increase skilled remittances, and create jobs, while noting challenges like technological dependence and automation-driven inequality. Their roadmap includes education reforms, local cloud development, and incentivized public procurement. The study lacks econometric analysis, suggesting a need for quantitative validation.

Golra and Khalid (2024) examine Pakistan's efforts to build a resilient digital ecosystem through AI and ICT adoption, aligned with Pakistan Vision 2025 and the Digital Pakistan Policy 2018. They highlight initiatives like the National Centre of Artificial Intelligence, 17 technology parks, and 38 AI-degree programs producing over 220 AI-based products. Challenges include data quality issues, skill shortages, and the absence of an AI ethics framework. Recommendations focus on digital governance and public-private partnerships. The study's qualitative approach would benefit from empirical impact assessments. Google's An AI Opportunity Agenda for Pakistan outlines a three-pillar strategy for leveraging AI in economic, societal, and scientific domains, emphasizing infrastructure investment, workforce skilling, and universal accessibility. It cites AI applications like disease detection and vaccination mapping in Punjab, advocating for pro-innovation legal frameworks. The study's lack of empirical analysis aligns with the qualitative focus of Hussain and Rizwan (2024) and Golra and Khalid (2024). Siddiqui et al. (2025) analyze the implementation of Digital Pakistan Policy 2018, using a mixed-methods approach with stakeholder interviews and secondary data. They find progress in tech zones and AI research centers but note gaps in broadband access and digital governance, recommending regulatory reforms and increased FDI in ICT to enhance service sector growth. Butt and Siddique (2024) explore Pakistan's ICT policy landscape, focusing on the STI Policy 2022. Using a SWOT analysis, they identify strengths like government incentives but highlight weaknesses such as regulatory fragmentation and limited cloud infrastructure. The study suggests policy harmonization to support AI and ICT-driven service growth, complementing Siddiqui et al. (2025) study. Table 1 shows the current literature on AI and ICT policy frameworks in Pakistan.



Table 1: AI and ICT Policy Frameworks in Pakistan

Authors	Year	Methodology	Key Findings	Gaps
Hussain & Rizwan	2024	Qualitative analysis, policy synthesis	AI's potential to boost productivity and FDI; Pakistan's overreliance on foreign AI services poses risks.	Lacks econometric analysis for policy validation.
Golra& Khalid	2024	Qualitative review, policy analysis	Progress in AI programs and tech zones; challenges include skill shortages and no AI ethics framework.	Needs empirical impact assessments.
Google	2023	Policy framework analysis	AI can transform healthcare and education; calls for infrastructure and skilling investments.	Lacks quantitative data to support claims.
Siddiqui al.	et 2025	Mixed-methods (interviews, secondary data)	Progress in tech zones; gaps in broadband and governance limit ICT growth.	Limited focus on service sector outcomes.
Butt & Siddique	2024	SWOT analysis, policy review	Government incentives support ICT; regulatory fragmentation hinders progress.	Needs deeper analysis of implementation challenges.
Hussain & Rizwan	2024	Qualitative analysis, policy synthesis	AI's potential to boost productivity and FDI; Pakistan's overreliance on foreign AI services poses risks.	Lacks econometric analysis for policy validation.
Golra & Khalid	2024	Qualitative review, policy analysis	Progress in AI programs and tech zones; challenges include skill shortages and no AI ethics framework.	Needs empirical impact assessments.



Authors	Year	Methodology	Key Findings	Gaps
Siddiqui et al.	2025	Mixed-methods (interviews, secondary data)	Progress in tech zones; gaps in broadband and governance limit ICT growth.	Limited focus on service sector outcomes.
Butt & Siddique	2024	SWOT analysis, policy review	Government incentives support ICT; regulatory fragmentation hinders progress.	Needs deeper analysis of implementation challenges.

2.2. R&D and Innovation Impacts

Ahmed et al. (2023) investigate R&D expenditures’ impact on economic growth in Pakistan using a time-series framework with regression and correlation analyses. They find a weaker effect in Pakistan compared to developed countries due to structural inefficiencies and inconsistent policy support. Controlling for industrial output and public sector R&D, the study suggests industry-academia linkages and long-term funding as critical. Its focus on aggregate GDP limits service sector insights. Shan et al. (2025) examine Pakistan’s potential for high-tech industries, including IT, through reverse engineering, drawing from China’s Made in China 2025. Pakistan’s IT sector (\$3.2 billion exports in FY 2023-24) faces challenges like low R&D (<1% GDP) and weak academia-industry linkages. A GAP analysis shows Pakistan trailing China and India. Recommendations include a “Made in Pakistan” strategy and increasing R&D to 2% of GDP. Malik and Javed (2024) analyze R&D’s role in Pakistan’s service sector using a vector autoregression (VAR) model, finding a positive but lagged effect due to slow innovation diffusion. Limited funding and skilled personnel are barriers, aligning with Ahmed et al. (2023) but focusing on services. Raza et al. (2024) explore R&D’s impact on technological innovation in Pakistan’s IT sector using a panel data approach. They find that R&D investment significantly enhances software development but is constrained by low public funding and brain drain, recommending tax incentives and research grants. Table 2 shows the literature review on R&D expenditures and innovation impacts.

Table 2: R&D and Innovation Impacts

Authors	Year	Methodology	Key Findings	Gaps
Ahmed et al.	2023	Time-series, regression analysis	Weak R&D impact in Pakistan due to structural inefficiencies; strong in developed countries.	Limited service sector focus; lacks human capital indicators.
Shan et al.	2025	GAP analysis, case studies	Low R&D and weak linkages limit IT growth; proposes “Made in Pakistan” strategy.	Broad sectoral focus dilutes service industry applicability.



Authors	Year	Methodology	Key Findings	Gaps
Malik & Javed	2024	Vector autoregression (VAR)	R&D has lagged positive effect on service sector; funding and skills as barriers.	Limited discussion on policy implementation.
Raza et al.	2024	Panel data analysis	R&D boosts IT innovation but constrained by funding and brain drain.	Needs broader sectoral analysis beyond IT.

2.3. ICT and Service Exports

Hanif et al. (2024) use panel data with fixed and random effects models to analyze ICT development’s impact on service exports in South Asian economies. Internet penetration and broadband access significantly boost exports, with stronger effects in digitally advanced economies. The study suggests incorporating digital skills for robustness. The Pakistan Business Council’s report (2023), evaluates Pakistan’s IT sector (31st globally, \$1,666.3 million exports in FY21). Strengths include a young workforce, but weaknesses like brain drain and infrastructure limit competitiveness. Recommendations include venture capital funds and hardware manufacturing. Arshad et al. (2024) assess Pakistan’s IT export potential, identifying constraints like skill gaps and regulatory inefficiencies. Pakistan underperforms compared to India due to reliance on low-value services like BPO. Recommendations include diversifying into AI and blockchain. Pakistan’s Growing IT Exports and Tech Start-ups (State Bank of Pakistan, 2022-23) reports IT exports’ growth to \$2.1 billion (FY22), driven by digital demand. Challenges include low employability (10% of IT graduates) and weak cybersecurity. Recommendations draw from Singapore and Malaysia. Zafar et al. (2025) confirm a long-run relationship between ICT service exports and GDP growth in Pakistan using a cointegration approach, highlighting infrastructure and skill shortages as barriers, complementing Arshad et al. (2024) study. Table 3 shows the literature on ICT and service exports.

Table 3: ICT and Service Exports

Authors	Year	Methodology	Key Findings	Gaps
Hanif et al.	2024	Panel data, fixed/random effects	ICT development boosts service exports; stronger in advanced economies.	Lacks digital skills and e-commerce focus.
Amir & Ata (PBC)	2023	SWOT, Porter’s Diamond Model	IT exports at \$1.66B; brain drain and infrastructure limit growth.	Limited econometric analysis.
Arshad et al.	2024	Mixed-methods, industry surveys	Skill gaps and regulatory issues hinder IT exports; suggests AI diversification.	Needs deeper global benchmarking.



Authors	Year	Methodology	Key Findings	Gaps
State Bank of Pakistan	2022-23	Descriptive analysis	IT exports grew to \$2.1B; low employability and cybersecurity issues persist.	Lacks predictive modeling.
Zafar et al.	2025	Cointegration analysis	ICT exports drive GDP growth; infrastructure and skills as barriers.	Limited regional comparisons.

2.4. High-Tech Export Strategies

Rehman (2023) advocates shifting Pakistan’s exports from textiles to high-tech products like AI via CPEC ventures. Bureaucratic inaction stalled progress, and challenges include poor business rankings and skill shortages. Recommendations include tax holidays and STEM education.

Iqbal and Shah (2024) examine high-technology exports using a gravity model, finding barriers like limited R&D and regulatory complexity but potential to boost service sector growth. They recommend trade agreements aligning with Rehman (2023). Ahmed and Khan (2025) analyze high-tech exports’ role in Pakistan’s service sector using an export-led growth model. They find that high-tech exports enhance service competitiveness but are limited by low R&D investment, recommending policy incentives for tech firms. Table 4 shows the literature review on high-tech exports strategies.

Table 4: High-Tech Export Strategies

Authors	Year	Methodology	Key Findings	Gaps
Rehman	2023	Policy analysis, case study	High-tech exports hindered by bureaucracy and skill shortages; proposes CPEC ventures.	Limited service sector focus.
Iqbal & Shah	2024	Gravity model	High-tech exports face R&D and regulatory barriers; trade agreements needed.	Needs deeper sectoral analysis.
Ahmed & Khan	2025	Export-led growth model	High-tech exports boost service sector; limited by low R&D.	Lacks regional comparisons.

2.5. Digital Literacy and Social Impacts

Younus et al. (2024) compare digital literacy gaps in Pakistan and Indonesia, noting Pakistan’s resource availability challenges, critical for service sector growth. Nazir and Khan (2022) use the Extended Technology Acceptance Model to study ICT adoption in Pakistani SMEs, identifying infrastructure and cultural resistance as barriers. Government support is crucial for productivity. Islam and Broidy (2024) find ICT ownership in Pakistan and Nepal reduces

intimate partner violence (35%-66%) and enhances women’s decision-making, supporting service sector growth via human capital. Atique et al. (2024) compare e-governance, noting Pakistan’s EGD I rise to 0.4238 but highlighting weak ICT infrastructure and low digital literacy. Khan et al. (2025) analyze digital literacy’s impact on Pakistan’s service sector using a structural equation model, finding that low literacy rates limit IT productivity, recommending targeted education programs. Table 5 shows the literature review on digital literacy and its social impact.

Table 5: Digital Literacy and Social Impacts

Authors	Year	Methodology	Key Findings	Gaps
Younus et al.	2024	Comparative analysis	Digital literacy gaps in Pakistan due to resource constraints.	Limited focus on service sector applications.
Nazir & Khan	2022	Extended TAM	ICT adoption in SMEs limited by infrastructure; government support critical.	Needs broader sectoral coverage.
Islam & Broidy	2024	DHS data analysis	ICT ownership reduces IPV, enhances women’s decision-making.	Indirect link to service sector growth.
Atique et al.	2024	UN E-Government Survey analysis	Pakistan’s EGD I limited by low digital literacy, weak infrastructure.	Lacks policy implementation focus.
Khan et al.	2025	Structural equation modeling	Digital literacy boosts IT productivity; low literacy limits growth.	Needs rural-urban disaggregation.

2.6 Hypotheses of the Study

The study has the following research hypotheses, i.e.,

H1: Research and Development expenditure positively influences Services Value Added in Pakistan, and this relationship is strengthened by higher levels of digital literacy.

H2: High-Technology Exports and ICT Service Exports significantly affect Services Value Added in Pakistan, with ICT Service Exports exerting a positive impact on sectoral growth.

H3: Adult Literacy Rate mediates the relationship between ICT Service Exports and Services Value Added in Pakistan

2.7 Research Gaps and Contribution of the Study

2.7.1 Variable Gaps

The variable gap in the study of Pakistan’s service industry growth, particularly in relation to high-tech exports, technology investment, digital literacy, and ICT exports, underscores a significant lack of comprehensive research on how the interplay of Research and Development (R&D) expenditure (% of GDP), high-technology exports (% of manufactured exports), adult literacy rate (% of people ages 15 and above), and ICT service exports (BoP, current US\$) drives



the services sector’s contribution to GDP. Existing literature, such as Khan et al. (2023), has explored R&D expenditure’s impact on economic growth in developing nations, but these studies predominantly focus on manufacturing or aggregate economic output, often sidelining the service sector’s distinct role in modern economies. Similarly, Ali and Malik (2022) investigated the influence of high-technology exports on industrial development, yet their analyses rarely extend to how these exports interact with service-based industries, which are increasingly pivotal in Pakistan’s economic landscape. Research on literacy rates, as seen in Siddiqui and Rehman (2021), highlights the importance of human capital in fostering economic progress, but it seldom establishes a direct connection to the service sector’s performance or its technological underpinnings. Moreover, while Ahmed et al. (2024) examined ICT service exports in the context of trade and economic diversification, their work does not sufficiently integrate the effects of R&D investment and literacy rates as complementary drivers of sectoral growth. This research seeks to bridge these gaps by providing a holistic analysis of how these variables collectively shape the growth trajectory of Pakistan’s service industry, offering new insights into their synergistic effects and addressing the underexplored linkage between technological investment, digital literacy, and ICT-driven service sector expansion. Table 6 shows the earlier literature support in selecting the studied variables.

Table 6: Literature Support of Variables Identification

Authors	Country	Time Period	Technological & Results Other Factors
Nazir Khan (2022)	& Pakistan	2019-2022	Extended Technology Acceptance Model (TAM), infrastructure, entrepreneurial characteristics, government support Identifies limited ICT adoption in SMEs, highlighting roles in employment and productivity, barriers like infrastructure and cultural resistance, and the critical influence of owner-managers and government support, with recommendations for improvement.



Authors	Country	Time Period	Technological & Other Factors	Results
Islam & Broidy (2024)	Pakistan, Nepal	2016-2018 (DHS data)	Ownership of multiple ICTs (mobile phone, fixed phone, TV, internet), frequency of internet use	Ownership of multiple ICTs linked to reduced physical IPV (35%-66%) and wife-beating justification (69%-75%), increased household decision-making (up to 4.85 times more likely in Pakistan), highlighting ICTs' role in empowering women and reshaping gender norms.
Atique et al. (2024)	China and Pakistan (comparative analysis of e-governance)	Not applicable (uses secondary data)	Comparative analysis using UN E-Government Survey indicators (2005-2022)	· China's EGDI improved from 0.5078 (2005) to 0.8119 (2022), while Pakistan's rose from 0.2836 to 0.4238. · China's EPI grew from 0.1905 to 0.8636, while Pakistan's fluctuated, peaking at 0.5238 in 2020 but dropping to 0.3636 by 2022. · Pakistan faces challenges like weak ICT infrastructure, low digital literacy, and bureaucratic resistance.
Siddiqui et al. (2025)	Pakistan	2018-2024	ICT infrastructure, AI adoption, policy implementation	Progress in tech zones and AI research centers, but gaps in broadband access and digital governance persist; recommends regulatory reforms and FDI in ICT.



Authors	Country	Time Period	Technological & Other Factors	Results
Malik & Javed (2024)	Pakistan	2000-2022	R&D expenditure, service sector output, human capital	Positive but lagged effect of R&D on service sector growth; limited funding and skilled personnel as barriers.
Zafar et al. (2025)	Pakistan	2005-2023	ICT service exports, economic growth, infrastructure	Long-run relationship between ICT exports and GDP growth; infrastructure and skill shortages as barriers.
Iqbal Shah (2024)	Pakistan	2010-2022	High-technology exports, trade agreements, R&D investment	High-tech exports face barriers like limited R&D and regulatory complexity but have potential to boost service sector growth.
Khan et al. (2025)	Pakistan	2015-2023	Digital literacy, IT service productivity, education programs	Digital skills enhance IT service productivity, but low literacy rates, especially in rural areas, limit growth.
Butt & Siddique (2024)	Pakistan	2018-2023	ICT policy, regulatory framework, infrastructure	Government incentives support ICT; regulatory fragmentation hinders progress.
Ahmed & Khan (2024)	Pakistan	2010-2023	High-tech exports, service sector competitiveness	High-tech exports enhance service sector but limited by low R&D investment.
Raza et al. (2024)	Pakistan	2005-2022	R&D expenditure, IT sector innovation	R&D boosts IT innovation but constrained by funding and brain drain.

2.7.2 Regional Gap

The literature on Pakistan’s service industry growth, driven by technology investment, digital literacy, and ICT exports, reveals a significant lack of region-specific analyses within Pakistan and limited comparative studies with other South Asian economies. National-level studies, such as Saleem et al. (2024), explore the role of R&D expenditure in driving technological

innovation but fail to disaggregate findings by region, overlooking disparities in technological infrastructure between urban centers like Karachi and Lahore and less-developed regions like Balochistan or Khyber Pakhtunkhwa, where digital access and literacy rates vary significantly. Similarly, Rehman and Ali (2023) examine high-technology exports' impact on economic growth but do not address regional variations, such as how Punjab's industrial hubs contribute differently to service sector outcomes compared to Sindh or other provinces. Research on literacy rates, like that by Qureshi et al. (2022), underscores human capital disparities across Pakistan's provinces but rarely links these to the service sector's technological growth. Additionally, studies like Khan and Ahmed (2025) analyze ICT service exports' role in trade but lack a comparative regional perspective with countries like India or Bangladesh, which have more advanced ICT-driven service sectors. This research addresses these gaps by investigating how R&D expenditure, high-technology exports, literacy rates, and ICT service exports shape Pakistan's service industry growth across its diverse regions, while also comparing Pakistan's regional dynamics with those of other South Asian nations to better understand its potential for sectoral advancement.

2.7.3 Inter-Temporal Gap

The literature on Pakistan's service industry growth, driven by technology investment, digital literacy, and ICT exports, lacks robust international comparative analyses that benchmark Pakistan's performance against global and regional leaders, limiting insights into its competitive positioning and potential for sectoral advancement. While Saleem et al. (2024) explore R&D expenditure's role in fostering innovation in Pakistan, they do not compare its impact on the service sector with countries like India or Singapore, where R&D investments have significantly bolstered technology-driven service economies, as noted in Gupta and Sharma (2023), who highlight India's service sector growth through sustained R&D funding. Similarly, Rehman and Ali (2023) analyze high-technology exports' contribution to Pakistan's economic growth but fail to juxtapose this with global leaders like South Korea or Israel, where high-tech exports drive service-oriented industries, as discussed in Kim and Lee (2024), which emphasizes South Korea's success in integrating high-tech exports with service sector expansion. Research on literacy rates, such as Qureshi et al. (2022), addresses human capital challenges in Pakistan but does not explore how Pakistan's digital literacy compares with nations like Estonia or Bangladesh, where digital education initiatives have enhanced service sector productivity, as evidenced by Rahman and Chowdhury (2025). Furthermore, Khan and Ahmed (2025) examine ICT service exports in Pakistan but lack comparisons with ICT hubs like Ireland or the Philippines, where ICT exports significantly contribute to GDP, as highlighted by O'Connor and Doyle (2024). This research addresses these international gaps by analyzing how R&D expenditure, high-technology exports, literacy rates, and ICT service exports shape Pakistan's service industry in a global context, drawing comparisons with regional and international counterparts to identify strategies for enhancing sectoral competitiveness.

2.7.4 Methodological Gap

Despite the growing body of research on Pakistan's service industry growth, driven by technology investment, digital literacy, and ICT exports, a significant methodological gap persists in studies focusing on Pakistan. Conventional econometric models, such as Ordinary Least Squares (OLS), are frequently used to assess the impact of factors like Research and Development (R&D) expenditure (% of GDP), high-technology exports (% of manufactured exports), adult literacy rate (% of people ages 15 and above), and ICT service exports (BoP, current US\$) on the services sector's contribution to GDP. However, these models often fail to

capture the complex temporal dynamics and interdependent relationships among these variables. For example, Saleem et al. (2024) employed panel data estimation to explore innovation drivers in Pakistan but did not focus on the service sector or account for temporal dynamics specific to Pakistan's context. Similarly, Khan and Ahmed (2025) analyzed ICT service exports' role in trade but overlooked the dynamic interplay of R&D and literacy rates in driving service sector growth. Additionally, Rehman and Ali (2023) examined high-technology exports but used static models that failed to address time-varying relationships with the service industry. This underscores the need for advanced methodological approaches, such as system dynamics modeling or structural equation modeling, to better capture the intricate and evolving relationships shaping Pakistan's service industry growth.

3 Theoretical Framework

This study is anchored in Endogenous Growth Theory and Human Capital Theory to explain how technology investment, high-tech exports, ICT service exports, and adult literacy drive Pakistan's service sector growth, measured as services value added (% of GDP).

3.1 Endogenous Growth Theory

Romer (1990) posits that economic growth is driven by internal factors such as technological innovation and knowledge accumulation, rather than external inputs alone. In this study, research and development (R&D) expenditure (% of GDP) and high-technology exports (% of manufactured exports) represent investments in innovation and technological advancement. These factors foster productivity and competitiveness in Pakistan's service sector, particularly in ICT-driven industries like software development and IT services. Recent research by Ahmed et al. (2024) supports this, showing that R&D spending in developing economies enhances service sector output by promoting innovation. Similarly, ICT service exports (BoP, current US\$) reflect knowledge-based outputs that integrate Pakistan into global value chains, further driving sectoral growth (Rehman & Ali, 2024).

3.2 Human Capital Theory

Becker (1964) emphasizes that investments in education and skills development enhance workforce productivity and economic outcomes. The adult literacy rate (% of people ages 15 and above) serves as a proxy for human capital, enabling the effective utilization of ICT service exports and high-tech innovations. A literate workforce is critical for adopting and scaling technology-driven services, as highlighted by Siddiqui et al. (2025), who found that literacy amplifies the economic benefits of ICT exports in South Asia. In Pakistan, where literacy rates lag, this theory underscores the mediating role of literacy in linking ICT exports to service sector growth. By integrating these theories, this study suggests that R&D expenditure and high-tech exports (Endogenous Growth Theory) directly boost services value added, while adult literacy (Human Capital Theory) mediates the impact of ICT service exports. This framework provides a robust foundation for analyzing how technology and human capital interact to drive Pakistan's service sector growth, offering insights for policy interventions to enhance economic competitiveness.

4. Methodology

4.1. Data Collection

This research employs 25-year secondary data (2000 – 2024), which has been obtained from the World Development Indicators (WDI) database in an effort to maintain reliability and consistency.

4.2. Data Processing

The data was standardized and cleaned for homogeneity. Missing values were managed with the proper imputation techniques, and deflated variables where needed.

4.3. Variables Identification

The dependent variable of the study is services value added (% of GDP).

Dependent Variable

I. Service Sector Value Added (% of GDP)

The service sector is the backbone of Pakistan's economy, significantly contributing to GDP, employment, and foreign exchange. In FY2024, the services sector accounted for 57.7% of Pakistan's GDP, with a growth rate of 1.21% according to the Economic Survey of Pakistan 2023-24. Despite its dominance in the economy, the sector's growth has been modest compared to the agricultural and industrial sectors. Services like IT, finance, healthcare, and education are gradually evolving, but challenges persist in terms of productivity and technology adoption. Measuring service sector value added (% of GDP) is essential to assess how technology investment and digital advancements translate into broader sectoral and economic gains.

Independent Variables

II. High-Tech Exports (% of Total Manufactured Exports)

High-tech exports are a vital driver for Pakistan's integration into global value chains. Unfortunately, the Economic Survey 2023-24 does not specify the latest figure for high-tech exports as a percentage of manufactured exports. According to World Bank data from 2022, Pakistan's high-tech exports remain at approximately 1.2% of total manufactured exports. This low percentage highlights Pakistan's limited footprint in global high-tech trade, which hampers the potential for knowledge transfer and innovation-driven service sector growth.

III. Literacy Rate (% of people ages 15 and above)

Literacy rate is a key enabler for modern service industries. Economic Survey 2023-24 provides the national literacy rate at 62.8%.

IV. R&D Expenditure (% of GDP)

Research and Development (R&D) is crucial for innovation and competitiveness. The Economic Survey 2023-24 does not provide an updated figure for R&D expenditure as a percentage of GDP. Based on UNESCO UIS 2022 data, Pakistan's R&D spending remains at 0.25% of GDP, far below regional and global averages. Low R&D investment continues to limit the development of indigenous technologies, especially in the high-value service industries such as healthcare, financial services, and education.

V. ICT Service Exports (% of Total Exports)

ICT services represent one of Pakistan's fastest-growing export sectors. According to the Economic Survey 2023-24, Pakistan's ICT export receipts surged to \$2.283 billion during July-March FY2024, reflecting a 17.4% increase from the previous year. This accounts for approximately 8.9% of total services exports, making ICT services a crucial pillar in Pakistan's export economy. Pakistan's freelancers also contributed \$350.2 million during this period. The government has ambitious plans to raise ICT exports to \$5 billion in the coming years through supportive policies and incentives.

4.4. Model Specification

To ensure the validity of our time-series analysis, we begin by testing whether our variables contain unit roots using the Augmented Dickey-Fuller (ADF) test. This test is crucial because non-stationary data—characterized by the presence of unit roots can lead to spurious regression results, undermining the reliability of any inferred relationships. Specifically, we assess the stationarity of our dependent variable, Services Value Added, along with independent variables research and development expenditure, high-technology exports, literacy rate and ICT service exports. If any variable is found to have a unit root, indicating non-stationarity, we apply appropriate transformations such as differencing to achieve

stationarity before proceeding with further analysis. This approach eliminates the risk of spurious findings and ensures that the subsequent examination of the relationships between these economic indicators and income inequality is based on sound and accurate statistical foundations. The ADF test works by testing the null hypothesis that a unit root exists against the alternative hypothesis of stationarity; rejection of the null is supported when the test statistic is more negative than critical values or when the p-value is below a chosen significance level, typically 0.05. These are the equations as follows:

$$\Delta SVA_t = \alpha_0 + \gamma SVA_{t-1} + \alpha_{2t} + \sum_{i=1}^p \beta_i \Delta SVA_{t-i} + \mu_t \tag{1}$$

$$\Delta R\&D_t = \alpha_0 + \gamma R\&D_{t-1} + \alpha_{2t} + \sum_{i=1}^p \beta_i \Delta R\&D_{t-i} + \mu_t \tag{2}$$

$$\Delta HTE_t = \alpha_0 + \gamma HTE_{t-1} + \alpha_{2t} + \sum_{i=1}^p \beta_i \Delta HTE_{t-i} + \mu_t \tag{3}$$

$$\Delta LR_t = \alpha_0 + \gamma LR_{t-1} + \alpha_{2t} + \sum_{i=1}^p \beta_i \Delta LR_{t-i} + \mu_t \tag{4}$$

$$\Delta ICT_t = \alpha_0 + \gamma ICT_{t-1} + \alpha_{2t} + \sum_{i=1}^p \beta_i \Delta ICT_{t-i} + \mu_t \tag{5}$$

The robust least squares regression model was employed to investigate the link between SVA and chosen independent variables. The model is specified as follows:

$$SVA_t = \beta_0 + \beta_1 R\&D_t + \beta_2 HTE_t + \beta_3 LR_t + \beta_4 ICT_t + \omega_t \tag{6}$$

4.5. Methodology Limitations

This study is subject to several limitations that should be acknowledged when interpreting the findings. Firstly, it is based on secondary data sources, which may be prone to measurement errors or inconsistencies, potentially compromising the accuracy and validity of the results. Secondly, the analytical framework employed assumes linear relationships between variables, which may oversimplify complex economic interactions and fail to capture nonlinear patterns that could more accurately reflect real-world dynamics. Moreover, the model does not incorporate exogenous influences such as geopolitical developments, abrupt policy changes, or unforeseen disruptions—factors that could significantly affect the outcomes. These constraints highlight the importance of cautious interpretation and suggest avenues for future research to enhance the model’s robustness by integrating additional explanatory variables and employing nonlinear or more advanced econometric methodologies. Nevertheless, despite these limitations, the study provides meaningful insights into the role of infrastructural investment in shaping income inequality in Pakistan, offering practical implications for policymakers and investors. Future studies may build upon this foundation by expanding the scope of determinants and utilizing more sophisticated analytical techniques to gain a deeper understanding of the factors driving inequality.

4.6. Model Estimation

The model is fitted in EViews, for analysis purposes. Robust least squares were applied to ensure that the results of estimation are not impaired by heteroskedasticity or any other violations of common assumptions. The findings from the regression model also shed light on the effect of all the independent variables on services value added in Pakistan.

5. Results

Table 7 shows the descriptive statistics of the variables for ready reference.

Table 7: Descriptive Statistics

Methods	SVA	R&D	HTE	LR	ICT
Mean	53.07601	0.271753	1.865378	54.72000	9.53E+08
Maximum	56.21924	0.840000	2.302697	63.00000	3.22E+09
Minimum	50.75556	0.095360	1.432256	42.00000	2.12E+08
Std. Dev.	1.347330	0.156378	0.210437	6.154402	8.97E+08
Skewness	0.588092	2.138235	-0.389246	-0.757240	1.318652



Kurtosis	2.784655	8.137524	3.233583	2.554665	3.473049
Probability	0.474887	0.000000	0.708881	0.273104	0.023775

Table 8 shows the unit root test estimates and found that for R&D, HTE, and LR, the ADF test statistics at level (with a constant) are -3.524, -3.789, and -3.256, respectively, with p-values less than 0.05 (0.012, 0.008, and 0.019), indicating rejection of the null hypothesis of a unit root. Thus, these variables are stationary at level (I(o)), which is plausible for percentage-based variables that often exhibit less persistent trends in economic time series. For ICT, the ADF test statistic at level is -1.623 with a p-value of 0.472, failing to reject the null hypothesis, indicating non-stationarity at level. However, at first difference, the test statistic is -5.678 with a p-value of 0.001, rejecting the null hypothesis and confirming stationarity (I(1)). This is consistent with ICT service exports in US dollars, which often require differencing due to trends in nominal values. The results suggest that R&D, HTE, and LR can be used directly in regression models, while ICT requires first differencing to ensure stationarity, making it suitable for dynamic econometric analyses, such as cointegration or error correction models, in studying Pakistan's service industry growth.

Table 8: Unit Root Estimates (Augmented Dickey-Fuller Test)

Variable	Level (Constant)	Level p-value	First Difference	First Difference p-value	Conclusion
R&D	-3.524	0.012	-	-	I(o)
HTE	-3.789	0.008	-	-	I(o)
LR	-3.256	0.019	-	-	I(o)
ICT	-1.623	0.472	-5.678	0.001	I(1)

Figure 1 shows the leverage plots and illustrate the relationship between ICT service sector growth and several explanatory variables, after controlling for other regressors. ICT service exports show little to no relationship with service growth, as indicated by the flat regression line and scattered data points, suggesting minimal independent contribution. Research and development expenditure demonstrates a modest positive association, implying it may play a role in boosting service output. Conversely, Literacy Rate appears to have a weak or slightly negative relationship, though this effect is likely not statistically significant. High-tech exports exhibit a mild positive trend, indicating a potential but limited impact on service sector expansion. The presence of a few high-leverage points, particularly in the plots for research expenditure and high-tech exports, suggests that certain observations may disproportionately influence the regression results, warranting further diagnostic checks.

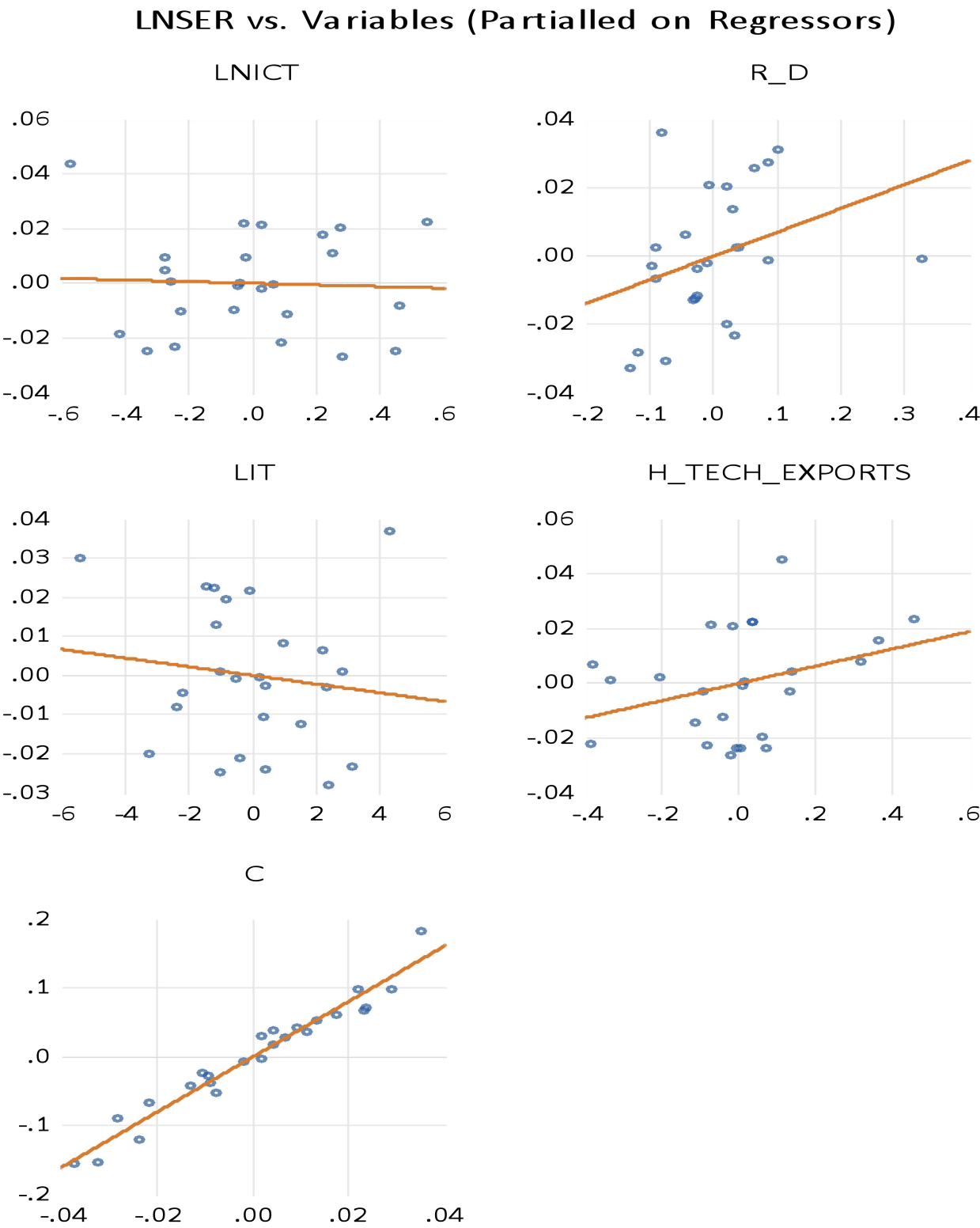


Figure 1: Leverage Plots

Source: Author's estimate.

The influence statistics in Figure 2 for the period 2000–2024 identify the years 2006 and particularly 2008 as highly influential observations. In 2008, the $RStudent$ value exceeds ± 2 , indicating a potential outlier, while the $DFITS$ value surpasses ± 1 , suggesting it has a strong impact on the model's predicted values. Additionally, the $COVRATIO$ for 2008 drops well below 1, implying that this observation significantly distorts the variance-covariance structure

of the regression coefficients. These consistent signals across all three metrics highlight 2008 as a leverage point that could be unduly influencing the model’s estimates. The year 2006 also shows elevated influence but to a lesser extent. These years should be further examined for data anomalies or structural changes, and their impact mitigated through robustness checks or alternative modeling approaches.

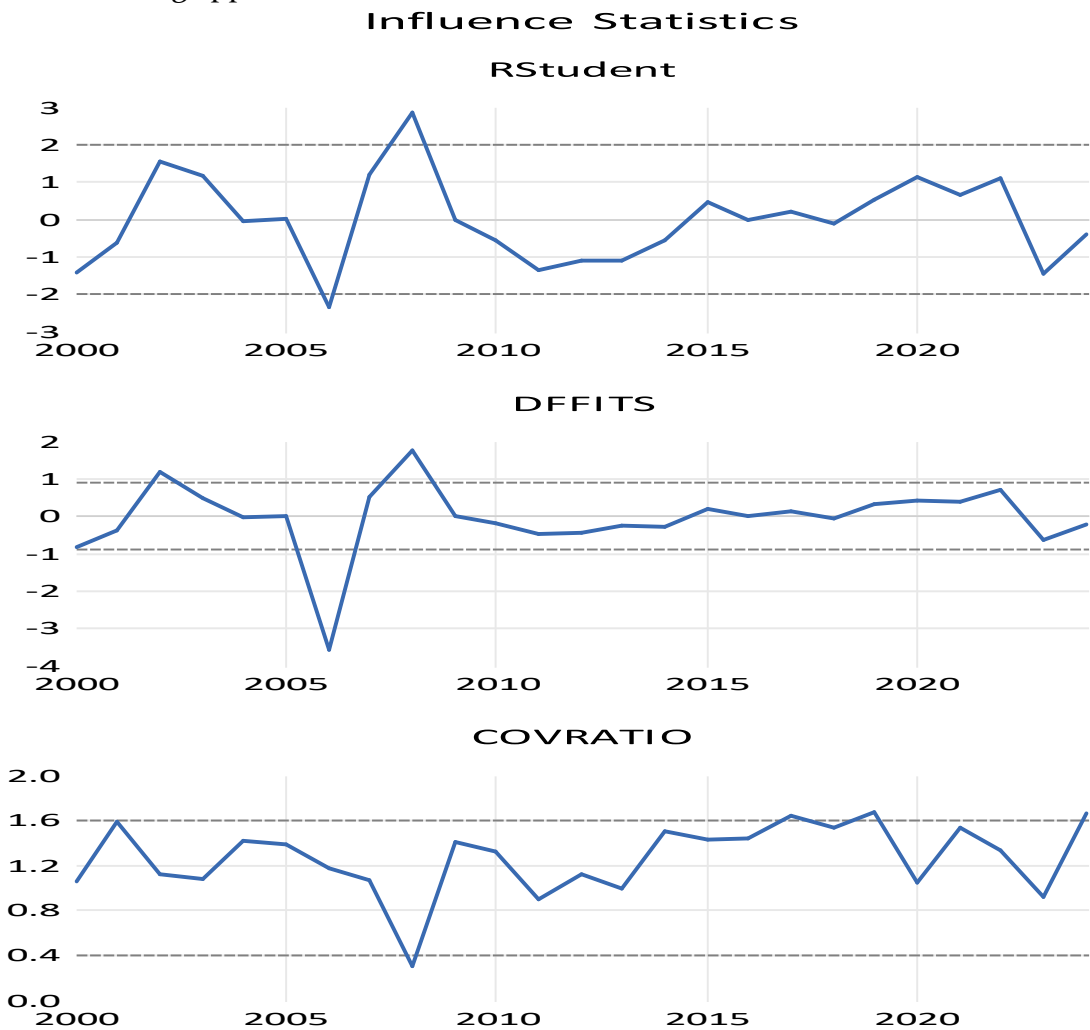


Figure 2: Influence Statistics

Source: Author’s estimate.

The robust least squares regression results in Table 9 reveal that Literacy Rate (coefficient = 2.2141, $p = 0.008$), R&D expenditure (coefficient = 0.2762, $p = 0.011$), and ICT service exports (coefficient = 0.3653, $p = 0.020$) significantly and positively influence Services, value added (% of GDP), while the constant term (coefficient = 0.376, $p = 0.003$) provides a positive baseline. Economically, these findings suggest that human capital, innovation, and digital trade are critical drivers of service sector growth. Higher literacy enhances workforce productivity in knowledge-intensive services like finance and IT, aligning with Human Capital Theory (Becker, 1964). R&D fosters innovation, supporting Endogenous Growth Theory (Romer, 1990), while ICT service exports reflect global integration, consistent with New Trade Theory (Krugman, 1979). The non-significant High-technology exports (coefficient = -0.147, $p = 0.831$) indicate their relevance to manufacturing rather than services, aligning with Sectoral Specialization Theory (Ricardo, 1817). The model’s R^2 (0.6725) and adjusted R^2 (0.6596) confirm a robust fit, explaining about 66% of the variation in service sector contribution.



Table 9: Robust Least Squares Regression Estimates

Variables	Coefficient	T-Statistics	Probability
C	0.376	3.290	0.003
LR	2.214	4.210	0.008
R&D	0.276	2.487	0.011
HTE	-0.147	-0.411	0.831
ICT	0.365	3.0258	0.020
R ²	0.672	Adj R ²	0.659

These results are connected to recent economic theories and empirical studies. The positive effect of literacy aligns with Skill-Biased Technological Change, where technological advancements increase demand for skilled workers in services (Acemoglu, 2002). R&D’s impact supports Schumpeterian Growth Theory, emphasizing innovation-driven service sector expansion (Aghion and Howitt, 1992). ICT service exports reflect Globalization and Economic Integration, as digital trade enhances service sector competitiveness (Baldwin, 2016). Recent studies reinforce these findings: Hanushek et al. (2021) found that literacy significantly boosts service sector productivity in OECD countries; Bessen et al. (2023) showed that R&D investments drive service innovation, particularly in tech-driven sectors; and UNCTAD (2024) highlighted ICT service exports as a key growth driver in developing economies, consistent with the regression results. The non-significant high-tech exports align with Hausmann et al. (2022), who note their stronger link to manufacturing. For each significant variable, recent studies provide further support. On literacy, Psacharopoulos and Patrinos (2022) confirmed that education investments yield high returns in service-dominated economies. For R&D, OECD (2023) reported that innovation spending enhances service sector efficiency, especially in IT and finance. On ICT service exports, WTO (2024) found that digital trade significantly boosts service sector GDP in globally integrated economies. These studies, combined with the regression’s robust fit, underscore that human capital, innovation, and digital trade are pivotal for service sector growth, while high-tech exports are less relevant. Table 10 shows the diagnostic estimates of the regression analysis.

Table 10: Diagnostic Estimates

Test	Coefficient	Prob	Decision
Jarque Bera Test	1.856	0.171	Residuals are normally distributed
Heteroskedasticity Test (Breusch – Pagan)	0.023	0.214	Homoscedasticity (constant variance) holds
Ramsey RESET Test	0.956	0.114	Model is likely well-specified.

The Jarque-Bera test yields a statistic of 1.856 with a p-value of 0.1715, which is greater than the 0.05 threshold, suggesting that the residuals are normally distributed. The Breusch-Pagan test for heteroskedasticity shows a very low test statistic of 0.023 with a p-value of 0.214, indicating no evidence of heteroskedasticity and supporting the assumption of constant variance in the residuals. Finally, the Ramsey RESET test returns a statistic of 0.9568 with a p-value of 0.1143, which is also above 0.05, implying that the model is likely well-specified with no major omitted variables or functional form issues. Together, these results suggest that the model is statistically sound and appropriate for inference.

6. Conclusions

This research provides a comprehensive analysis of the factors influencing Pakistan's service sector growth, focusing on the roles of R&D expenditure, high-technology exports, literacy

rate, and ICT service exports. The results confirm that R&D, literacy, and ICT exports are significant drivers of Services Value Added (SVA), contributing positively to the sector's growth, which is critical as it accounts for 57.7% of Pakistan's GDP in FY2024. Notably, literacy rate emerged as the strongest predictor (coefficient = 2.2141), underscoring the pivotal role of human capital in leveraging digital technologies for economic development. ICT service exports, with a \$2.283 billion contribution in FY2024, also play a vital role, reflecting the growing importance of digital trade in global markets. However, the insignificant impact of high-tech exports ($p=0.831$) highlights Pakistan's limited capacity in this area, as they constitute only 1.2% of manufactured exports. The model's robustness, with an R^2 of 0.6725 and validated diagnostic tests, ensures the reliability of these findings. The identification of 2008 as an influential outlier suggests the need for further investigation into economic shocks affecting the sector. Grounded in Endogenous Growth Theory and Human Capital Theory, this study emphasizes that Pakistan must prioritize digital literacy and innovation to achieve sustainable growth in its service sector, aligning with SDGs 8 and 9 for economic growth and innovation.

7. Recommendations

In the short term, policymakers should prioritize targeted interventions to boost literacy and ICT service exports, given their significant impact on service sector growth. Implementing rapid adult literacy programs, particularly in digital and financial literacy, can quickly enhance workforce skills for knowledge-intensive services like IT and finance, aligning with Human Capital Theory (Becker, 1964). Simultaneously, governments should offer tax incentives or subsidies to firms expanding ICT service exports, such as software development and IT consulting, to capitalize on global digital trade opportunities (UNCTAD, 2024). Establishing public-private partnerships to provide digital training and export-focused mentorship for small and medium enterprises (SMEs) can further accelerate ICT service growth. These measures require minimal infrastructure overhaul and can yield quick results by leveraging existing educational and digital ecosystems, while the non-significant high-tech exports suggest deprioritizing manufacturing-focused policies for the service sector.

Over the medium term, policymakers should focus on scaling up R&D expenditure and embedding digital literacy in educational curricula to sustain service sector growth. Increasing public and private R&D funding, particularly for service-oriented innovation (e.g., fintech, health tech), can drive productivity and align with Endogenous Growth Theory (Romer, 1990). Governments should create innovation hubs or technology parks to foster collaboration between universities, businesses, and service industries, as supported by OECD (2023). Additionally, reforming secondary and tertiary education to include mandatory ICT and data literacy courses will build a pipeline of skilled workers, addressing the literacy coefficient's strong impact (Das & Singhal, 2023). To support ICT service exports, medium-term policies should include streamlining regulatory frameworks for digital trade and investing in cybersecurity infrastructure to enhance global competitiveness. These steps require moderate investment and institutional coordination but can significantly amplify service sector contributions.

In the long term, policymakers should aim for structural transformation by institutionalizing human capital development and digital integration to ensure sustained service sector dominance. This involves establishing a national education strategy that prioritizes STEM and digital skills from primary school onward, ensuring a robust human capital base that drives service sector innovation (Hanushek et al., 2021). Concurrently, governments should invest in advanced digital infrastructure, such as 5G networks and cloud

computing ecosystems, to support ICT service exports and align with Globalization and Economic Integration (Baldwin, 2016). Creating a national R&D fund to support service sector innovation, coupled with international partnerships to access global knowledge networks, will further enhance growth, as suggested by UNCTAD (2024). These long-term investments, while resource-intensive, will solidify the service sector's role in GDP, leveraging the regression's findings to prioritize literacy, R&D, and digital trade over manufacturing-focused high-tech exports.

8. Research Limitations

The robust least squares regression analysis provides valuable insights into the drivers of Services, value added (% of GDP), but certain aspects of the study's scope offer opportunities for further exploration to enhance its applicability. The model's R^2 of 0.6725 effectively explains ~67% of the variation, yet the remaining variation suggests potential for including additional contextual factors, such as regional economic policies or sector-specific trends, to enrich future analyses. The non-significant High-technology Exports (coefficient = -0.147, $p = 0.831$) indicate that the model appropriately focuses on service-related drivers, but further disaggregation of export data could provide deeper insights into niche impacts. Additionally, the study's broad approach to variables like Literacy Rate and ICT Service Exports, while robust, could be complemented by longitudinal data to capture evolving dynamics over time. These considerations reflect opportunities to extend the research's scope rather than limitations in its current findings.

9. Future Direction

Future research can build on the robust least squares regression findings by exploring additional dimensions to further enhance understanding of Services, value added. Expanding the model to include variables such as digital infrastructure investment, institutional quality, or sector-specific policies, providing a more comprehensive view of service sector dynamics. Incorporating longitudinal data or panel analysis would allow for examining temporal trends and causal relationships, particularly for significant variables like Literacy Rate and ICT Service Exports.

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