Pakistan Institute of Development Economics

Policy Brief

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TECH INDEX PAKISTAN: A STATISTICAL APPROACH TO UNDERSTANDING THE RELATIONSHIP BETWEEN TECHNOLOGY, COMPETITION, AND GROWTH

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INTRODUCTION

Technology, Competition, and Economic Growth: A Global Perspective

Technology has become a critical driver of economic growth and development in today's world, transforming industries and creating new economic sectors through innovations like artificial intelligence, automation, and renewable energy. Countries that invest in technology and foster competitive markets have seen substantial benefits. The relationship between technological innovation and economic growth highlights the importance of fostering competition to encourage innovation and efficiency, as highlighted by neoclassical growth theory. To bridge gaps in technology adoption, especially in developing countries, it is essential to address structural barriers, enhance infrastructure, and prioritize research and development (R&D).

Pakistan's Technology Landscape: Challenges and Opportunities

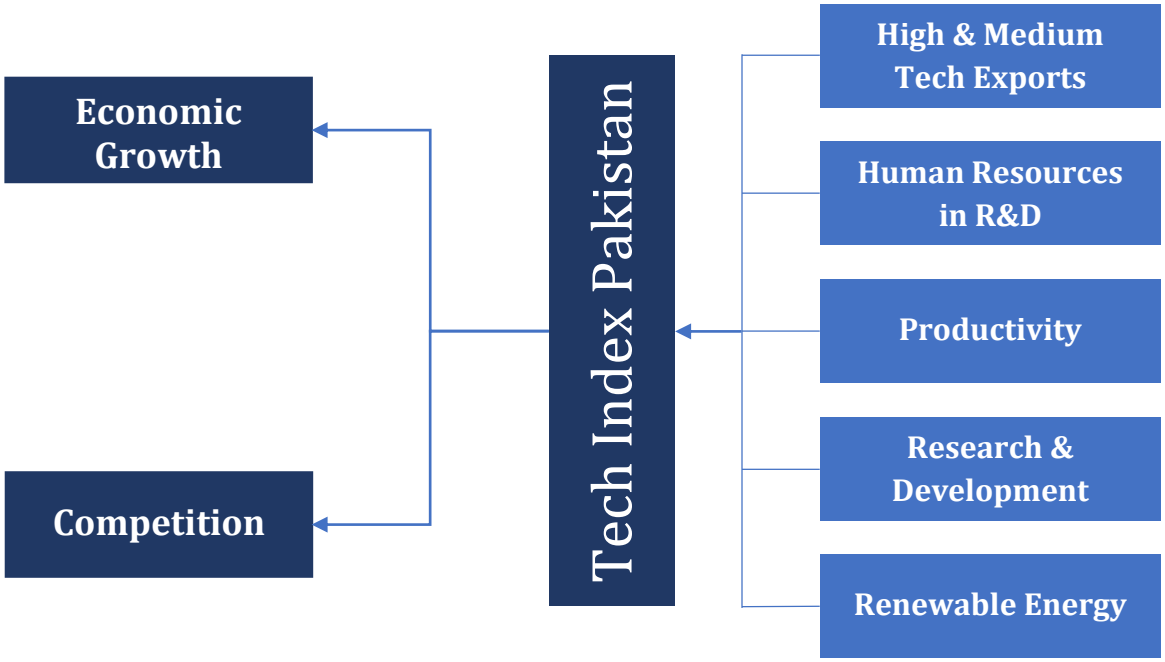
Pakistan has made significant strides in technological advancement over the past few decades, supported by a young population, a growing digital infrastructure, and initiatives like the Digital Pakistan Policy and Special Technology Zones. However, despite these opportunities, challenges such as limited R&D expenditure, inadequate STEM education, regulatory constraints, and a lack of venture capital hinder the country's ability to fully capitalize on its potential. These barriers, coupled with insufficient understanding of technology's economic impact, restrict technological development and, in turn, economic growth. This research seeks to address these challenges by proposing targeted solutions to enhance competition, innovation, and sustainable growth.

Building a Tech Index: Rationale and Approach

The rationale behind this study is rooted in the pressing need to understand the role of technology in driving economic competitiveness and growth. Thus, the primary objectives of this research project was to develop the technology index for Pakistan. This technology index depicts the country's overall situation concerning technology adoption, advancement, and proliferation. By thoroughly examining the dynamics of technological sophistication and competition, we tried to uncover how technological advancements shape the competitive market landscape and economic growth. The idea

was to synthesize the findings into data-driven recommendations. These recommendations have been tailored for policymakers and stakeholders.

Figure 1: Schematic Depiction of the Research Project



Scope and Policy Relevance of the Study

The scope of this study lies in the fact that there does not exist a wide-based understanding of how technology, competition, and economic growth come together in Pakistan. As such, this research came to bridge the critical knowledge gap by digging deep into these intricate relationships between the three pillars; technology, competition and economic growth. The study was aimed to catalyze a systematic exploration beyond surface-level observations through such an approach.

RESEARCH METHODOLOGY

Tech Index Composition and Construction

The Tech Index was developed as a comprehensive measure to evaluate technological adoption and advancement across Pakistan, Egypt, India, Sri Lanka, and Uzbekistan. Five sub-indicators were chosen for the composition of the index: patents, high-tech and medium-tech exports (EXP), labor productivity (PROD), human resources in R&D (HR), and renewable energy percentage of total consumption (RENEW) each sub-indicator was assigned an equal weight of 20%. To account for missing data, two indices were created: one using R&D expenditures and the other using patent

counts as proxies for technological advancement. Data for the sub-indicators was sourced from reputable international organizations, including UNIDO, UNESCO, ILOSTAT, and the World Bank. To address missing data, the EM-Algorithm was employed, as it is robust under the assumption that the missingness is "missing at random" (MAR), minimizing biases. Given the limitations of data availability, patent counts were deemed a reliable proxy for innovation outputs. The Min-Max normalization technique was used to preserve the relative differences across countries and allowed for intuitive interpretation of index values. After normalization, a geometric mean aggregation method was applied to compute the composite index. To ensure the robustness of the Tech Index, uncertainty and sensitivity analyses were conducted. The results showed that the index was stable over time and robust to methodological variations.

Post Index Econometric Analysis

Following the construction of the Tech Index, econometric analyses were conducted to explore the relationships between technological advancement, market competition, and economic growth. Two models were specified. The first analyzed the impact of technological advancement (measured by the Tech Index) on market competition, using industrial design applications as a proxy for competition. The second examined the relationship between economic growth (measured by GDP), competition, and technological advancement. Human development index (HDI) and foreign direct investment (FDI) were included as mediating and control variables, respectively. The econometric methodology included Ordinary Least Squares (OLS) and Two-Stage Least Squares (2SLS) regression techniques to address endogeneity concerns. For instance, FDI and the Tech Index were identified as potentially endogenous variables. To account for this, their lagged values were used as instruments in the 2SLS model. Diagnostic tests, such as the Durbin-Wu-Hausman test and Cragg-Donald F-statistic, validated the relevance and exogeneity of the instruments. Moreover, Toda-Yamamoto approach and impulse response functions (IRFs) were also applied to understand the directional and dynamic relationships among the variables.

RESULTS AND DISCUSSION

Tech Index Results

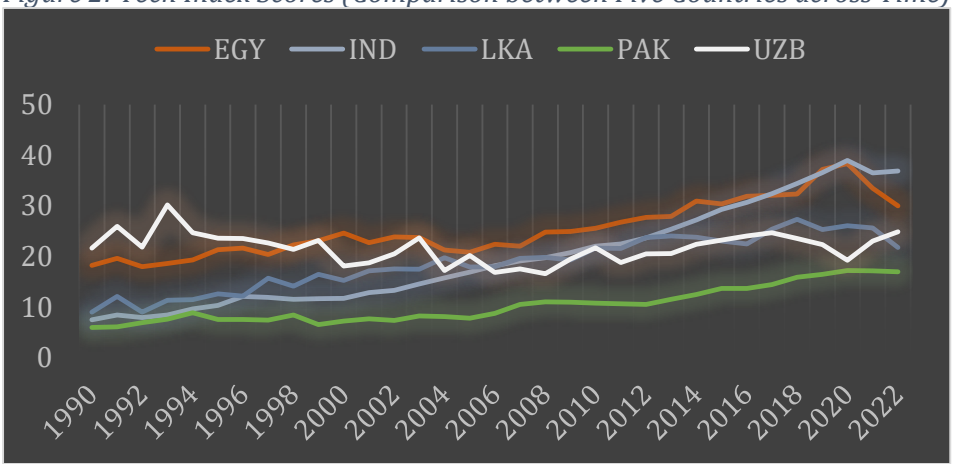
The Tech Index results reveal distinct disparities in technological advancement across the five countries studied: Pakistan, India, Egypt, Sri Lanka, and Uzbekistan. India and Egypt consistently outperform Pakistan in most sub-indicators, including patents, high-tech exports, labor productivity, and renewable energy adoption. Sri Lanka and Uzbekistan, while trailing behind India and Egypt, also rank higher than Pakistan in key areas such as human resources in R&D and renewable energy consumption, highlighting persistent structural and policy challenges. The consistency of the index across years further validated its reliability, providing a focused perspective on technological sophistication. Pakistan's stagnant performance in patents and human resources in R&D highlights systemic issues, such as inadequate funding and weak institutional frameworks. The sensitivity and

uncertainty analyses conducted on the index confirmed its stability, particularly for the patent-based version ensuring accuracy for the subsequent econometric analyses.

Impact of Policy Shocks on Tech Index: A Comparative Analysis

After, estimating the Tech index next step was to check the impact of policies, initiatives adopted by the governments on the tech index. Figure 4.1 presents Index 1 scores for five countries, including Egypt, India, Pakistan, Sri Lanka, and Uzbekistan, from 1990 to 2022. Pakistan has witnessed consistent but modest growth, peaking in 2020 at 17.22. Significant growth phases were observed from 1990 to 1994, 2005 to 2007, and 2012 to 2020. Sri Lanka and India started relatively just above Pakistan, such that the scores of India and Sri Lanka were 7.50 and 9.02, whereas that of Pakistan was 5.99. After 33 years, in 2022, India and Sri Lanka scored relatively much better than Pakistan at 36.89 and 21.81, where Pakistan scored 17. India has experienced an upward trend and shows signs of consistent growth from 1990 onwards. Sri Lanka also showed a positive growth trend but was modest compared to India. Its trajectory slowed and flattened, especially after 2012, and after an abrupt upsurge from 2016 to 2018, it started a declining trend until the end of 2022. Egypt also showed modest growth in its tech index scores. It showed a significant growth trend in its scores after 2007 but relatively slowed and started declining after 2019.

Figure 2: Tech Index Scores (Comparison between Five Countries across Time)



Post Index Estimations of Econometric Models, Toda-Yamamoto Causality and Impulse Response Functions (IRFs)

The first econometric model explored the relationship between technological advancement and market competition. The regression results, technological innovation led to increased market concentration, as dominant players capitalized on technological leadership, and monopolize the powers resulting in decrease in market competition. Foreign investments amplify the positive impacts of technological advancements on competition. The second model assessed the impact of technological advancement and competition on economic growth, measured by GDP. The findings confirmed a positive and significant relationship between the Tech Index and GDP growth, highlighting the critical role of technological progress in driving economic expansion. Competition,

mediated through technological innovation, also contributing positively to GDP, the Toda-Yamamoto causality analysis revealed significant bidirectional causality between technological advancement and economic growth, emphasizing their mutual reinforcement. Technological progress not only drives GDP growth but is also enhanced by economic expansion, as higher GDP enables increased investment in R&D and innovation. Unidirectional causality from technological advancement to competition was observed. The impulse response function analysis further validated the dynamic relationships among the key variables. Shocks to technological advancement produced a delayed but sustained positive impact on GDP, reflecting the long gestation period of innovation-driven growth. In contrast, the initial impact of technology on competition was negative, consistent with the concentration effects observed in Model 1. Over time, however, the effects turned positive, indicating market restructuring and enhanced competition.

CONCLUSION AND POLICY RECOMMENDATIONS

Conclusion

This study highlights the critical role of technological advancement in driving economic growth and fostering market competition. The Tech Index results reveal Pakistan's lagging performance compared to peers such as India and Egypt, underscoring structural weaknesses in patents, high-tech exports, R&D capacity, and renewable energy adoption. Econometric analyses confirm the interconnectedness of technology, competition, and growth, with human capital emerging as a pivotal factor. While Pakistan shows potential for improvement, bridging the technology gap requires focused, actionable policy interventions to address systemic challenges and unlock sustainable growth.

Policy Recommendations

1. Increase R&D Investment and Strengthen Innovation Ecosystems: At least 1% of GDP needs to be spent on R&D to strengthen technological innovation according to international norms. Dedicated R&D hubs formed in cooperation with the private sector, would bring about an enabling ecosystem for innovation.

2. Promote High-Tech Exports and Renewable Energy Development: Targeted incentives, including tax rebates and export subsidies, are needed to attract high-tech manufacturing and export-oriented industries. This will have to be supplemented with fast-tracking renewable energy projects under the Alternative and Renewable Energy Policy 2019 and creating public-private partnerships to attract foreign investment in the sector.

3. Centralized National Technology Transfer Office (TTO): To bridge the gap between research and commercialization, Pakistan should establish a centralized National Technology Transfer Office (TTO). This office would facilitate collaboration between academia, research institutions, and industries to ensure that R&D outputs are transformed into market-ready innovations. The TTO

should provide legal, financial, and logistical support for patent filings, licensing agreements, and technology deployment.

4. Competitive Technology Fund (CTF): Pakistan should create a Competitive Technology Fund (CTF) to incentivize innovation in high-tech sectors such as IT, renewable energy, and biotechnology. The fund should be performance-based, awarding grants or low-interest loans to companies and startups demonstrating high-impact technological advancements. A dedicated portion of this fund should focus on fostering regional innovation hubs, particularly in underdeveloped areas, to ensure inclusive growth. This approach aligns with India's Technology Development Fund (TDF), which has significantly boosted industry-led innovation.