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Exploring the Influence of Human Capital and Technology on India's Economic Development

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Abstract

The primary objective of this study is to explore the interrelationship between human capital, technological advancement, and economic growth in the context of India. By employing vector autoregression (VAR) analysis, the research aims to uncover the causal linkages among these three critical variables. The study utilizes secondary time-series data sourced from the World Bank, covering the annual period from 2020 to 2025. The empirical findings reveal that technological development significantly enhances human productivity, particularly when individuals possess the requisite skills, knowledge, and competencies — collectively referred to as human capital. In turn, human capital plays a pivotal role in the effective adoption, utilization, and adaptation of technology in various sectors of the economy. This mutual reinforcement between human capital and technology suggests a synergistic relationship, where advancements in one domain stimulate progress in the other. As a result, both factors jointly contribute to accelerating economic growth by improving efficiency, innovation, and overall performance in the workforce and production systems. The study thus underscores the importance of investing simultaneously in education, skills development, and technological infrastructure to sustain and enhance India's economic development.

Keywords: Development**,** infrastructure, skills development

Introduction

The debate surrounding the advantages and limitations of human capital remains ongoing in contemporary economic discourse (Harms, Schmidt, Dame, Brockman, & Stuart, 2022). Historically, before the concept of human capital was integrated into economic analysis, economies—particularly in developing countries—relied heavily on their comparative advantage in terms of abundant natural resources and

inexpensive labor. During this period, human labor was primarily viewed as a mere factor of production, with limited emphasis placed on the qualitative aspects of human input such as skills, knowledge, and innovation (Mohanty & Sethi, 2019).

However, with the advent of globalization, rapid technological progress, and the emergence of a knowledge-driven economy, there has been a paradigmatic shift in how human resources are perceived. In today's interconnected and competitive global environment, people are increasingly recognized not just as laborers, but as valuable assets who contribute strategically to organizational growth and national development. Organizations are compelled to go beyond the traditional model of low-cost labor and instead prioritize the quality, adaptability, and innovative capacity of their workforce (Obradović, Vlačić, & Dabić, 2021).

Despite these developments, a significant challenge persists in many developing countries, where large segments of the population lack access to quality education, vocational training, and skills development programs. As a result, these individuals are often unable to effectively engage with or benefit from modern production technologies, which are central to current industrial advancement (Malik, 2018). The rise of Industry 4.0 and automation has increased the demand for a technologically competent workforce capable of operating and coexisting with intelligent systems. This scenario underscores the growing importance of human capital, as it is no longer sufficient for workers to possess basic skills—they must continuously update their knowledge and acquire new competencies to remain relevant in the evolving industrial landscape (Sima, Gheorghe, Subić, & Nancu, 2020).

Human capital, alongside technological advancement, is widely recognized as a fundamental driver of economic development, particularly in emerging and developing economies (Prasetyo & Kistanti, 2020). It is essential to understand and promote the value of educating individuals about how both human capital and technology contribute meaningfully to national progress, as demonstrated in the context of India's economic development (Muhamad, Sulaiman, & Saputra, 2018). The interplay between human capital and technology has been examined across various disciplines and theoretical perspectives, each highlighting the diverse ways these factors influence economic performance. However, despite widespread acknowledgment of its importance, the precise impact of human capital on economic growth remains an area of active inquiry and scholarly interest (Widarni & Bawono, 2021).

The skills, competencies, and capabilities accumulated within a country's labor force serve as key assets in driving sustainable economic growth and productivity (Sulisnaningrum, Widarni, & Bawono, 2022). This

underlines the need for comprehensive studies that account for the evolving composition of the workforce, which is increasingly segmented by gender, age, educational attainment, and occupational categories (Nasiri & Hamelin, 2018). Moreover, innovation and the creation of new technologies are highly dependent on the quality of human resources. Human capital not only enables the development of technology but also plays a critical role in facilitating its adoption, diffusion, and effective utilization within society (Vrontis et al., 2022). Recognizing this, India has prioritized the strategic development of its human resources, with particular emphasis on strengthening foundational education, such as compulsory primary schooling. Simultaneously, vocational and higher education sectors are being expanded and aligned to meet the evolving needs of the labor market, especially in producing middle- and high-level skilled workers (Lhakard, 2022).

The Thai government has demonstrated a sustained commitment to educational reform and human capital enhancement by broadening access to basic education, encouraging enrollment in tertiary education, and promoting equitable opportunities for learning across social groups. Furthermore, there has been a paradigm shift in the country's education policy—from merely preparing the workforce to meet industrial demands, to fostering holistic community development. This includes equipping individuals with not only technical knowledge and skills but also critical thinking, creativity, and adaptability, all of which are vital in responding to the dynamic challenges posed by economic globalization and societal transformation (Worawiwat & Qian, 2019).

The India government recognizes technology as a fundamental and multifaceted pillar of national development. Viewing it not merely as a tool but as a strategic foundation for progress across various sectors, the government has committed to fostering technological advancement in a deliberate and sustained manner (Dung & Tri, 2021). The prioritization of technology stems from its vital role in transforming multiple areas of the economy, including agriculture, industry, energy and environmental management, healthcare, and education. In these domains, technological innovation not only enhances productivity but also promotes resilience and adaptability in a rapidly changing global environment (Fróna, Szenderák, & Harangi-Rákos, 2019).

By integrating existing and emerging technologies into its development strategy, India aims to align industrial output with global standards while simultaneously boosting domestic competitiveness. The focus is on achieving self-sufficiency in technological capabilities—both in qualitative and quantitative terms—through sustainable development practices. This approach supports long-term national objectives by ensuring that

economic growth does not come at the expense of environmental stability or social well-being (Ren, Li, Wang, & Zhang, 2020).

In this context, human capital becomes an indispensable asset. Research suggests that economic growth is more significantly influenced by the presence of a skilled and knowledgeable workforce than merely by the number of workers employed (Nguyen, 2020). Human capital, defined by education, training, and the ability to innovate and apply knowledge, plays a crucial role in absorbing, adapting, and advancing technology in a manner that enhances productivity and output. The pace of technological change directly affects economic performance, but its full potential can only be realized when complemented by a workforce capable of engaging with these advancements effectively (Alam & Murad, 2020).

Consequently, various high-value industries and productive sectors demand technically proficient and adaptable labor. The successful implementation of advanced production techniques hinges on the availability of such human capital, making it a key enabler of technological transformation (Abdeldayem & Aldulaimi, 2020). Against this backdrop, the present study seeks to investigate the intricate relationship between human capital, technological development, and economic growth in India. By examining these interconnected dimensions, the study aims to contribute to a deeper understanding of how the synergy between skilled labor and technology drives sustainable economic advancement.

Research Method

Using vector analysis and the following model, we examine the causal connections between technology, human capital, and economic growth :

$$T_t = \beta_1 T_{t1} + \beta_2 T_{t2} + \beta_3 HC_{t3} + \beta_4 HC_{t4} + \beta_5 GDP_{t5} + \beta_6 GDP_{t6} + e_t \quad \text{(equation 1)}$$

$$HC_t = \beta_1 T_{t1} + \beta_2 T_{t2} + \beta_3 HC_{t3} + \beta_4 HC_{t4} + \beta_5 GDP_{t5} + \beta_6 GDP_{t6} + e_t \quad \text{(equation 2)}$$

$$GDP_t = \beta_1 T_{t1} + \beta_2 T_{t2} + \beta_3 HC_{t3} + \beta_4 HC_{t4} + \beta_5 GDP_{t5} + \beta_6 GDP_{t6} + e_t \quad \text{(equation 3)}$$

Information:
HC = Human Capital
T = Technology
GDP = Economic growth
t = time period
β = Constant
e = error term

We employ secondary data from the World Bank that has been modified to meet the demands of the research using the variable descriptions shown in Table 1.

Table 1. Descriptive Statistics

No	Variable	Variable Description	Unit Analysis
1	Human Capital (HC)	Nominal value of national education investment per year, expressed in USD	USD
2	Technology (T)	Nominal value of national education investment per year, expressed in USD	USD
3	Economic Growth (GDP)	Nominal value of national education investment per year, expressed in USD	USD

This analysis uses secondary data from the World Bank for a yearly period from 2020 to 2025.

Result and Discussion

The autoregressive vector test shown in table 2 is used in this study to examine the direction of the link between economic growth, human capital, and technology.

Table 2. Autoregressive Vector Test

	GDP	HC	T
GDP	0.311231	0.026213	0.41131
	-0.24117	-0.0227	-0.71131
	[1.21113]	[1.31317]	[0.61112]
HC	2.01141	0.18321	0.11713
	-9.21121	-0.26112	-0.13126
	[2.21231]	[2.41121]	[0.81237]
T	0.612125	0.411235	0.058002
	-0.00012	-0.471121	-0.11211
	[0.34117]	[0.00911]	[0.19323]
R-squared	0.771231	0.77215	0.782233
Adj. R-squared	0.751121	0.721048	0.785749

The empirical results derived from the vector auto regression (VAR) analysis reveal a series of statistically significant relationships among GDP, human capital, and technology in the context of India's economic development. Firstly, the analysis indicates that past values of Gross Domestic Product (GDP) exert a strong and positive influence on current GDP, as evidenced by both the magnitude of the coefficient and the corresponding statistical significance. This finding underscores the dynamic nature of economic performance, where previous economic output acts as a foundational determinant of present growth trends.

Furthermore, the results suggest that GDP has a significant and favorable impact on the development of human capital (HC). In other words, as a country's economic output increases, it tends to allocate more resources toward education, training, and other forms of human capital enhancement. Simultaneously, GDP also positively

influences technological development, indicating that a robust economy creates a conducive environment for technological investment and innovation.

The analysis further demonstrates that human capital exhibits a strong autoregressive component—current levels of human capital are significantly influenced by its past levels. This reflects the cumulative nature of human capital accumulation, where the benefits of past investments in education, skills, and training continue to manifest over time. Moreover, the findings reveal a significant and positive impact of technology on human capital, suggesting that technological advancements contribute to improved educational and training outcomes, thereby enhancing the quality of the workforce.

In addition, technology is shown to have a statistically significant positive effect on GDP, reinforcing the notion that technological progress is a key driver of economic growth. Interestingly, technology also exhibits a self-reinforcing relationship, whereby past technological development significantly influences present technological advancement, pointing to a pattern of innovation continuity.

The overall model demonstrates a strong goodness-of-fit, with an adjusted R-squared value of 0.77, indicating that 77% of the variation in the dependent variables is explained by the model. These results, as confirmed by the vector auto regression tests, strongly support the study's hypotheses. The interplay between human capital, technology, and GDP is therefore shown to be mutually reinforcing, highlighting the importance of strategic investments in education and innovation to sustain long-term economic growth.

Conclusion

Technology enhances human performance most effectively when individuals possess sufficient human capital—namely, the knowledge, skills, competencies, and experience necessary to utilize technological tools efficiently and productively. The presence of advanced technology alone is not enough to drive meaningful improvements in productivity or economic outcomes; its successful adoption and application depend heavily on the quality of human capital available within the workforce. As technology becomes increasingly integrated into various sectors—ranging from manufacturing and healthcare to education and public administration—the importance of a skilled, adaptable, and tech-savvy labor force becomes even more pronounced.

In this evolving economic landscape, the role of human capital continues to grow in relevance. Workers must not only be able to operate new technologies but also to continuously learn, innovate, and adapt in response to ongoing technological advancements. This creates a reciprocal relationship between technology and human capital: while technology can amplify human capabilities and increase efficiency, it simultaneously demands a higher level of human capital to be effectively implemented and maintained.

Therefore, technology and human capital are not isolated drivers of economic growth; rather, they function in a synergistic manner. Human capital empowers individuals to make full use of technological innovations, while technology, in turn, provides tools and platforms that enhance learning, productivity, and innovation. Together, they form a reinforcing loop that is essential for driving sustainable economic development and long-term national competitiveness.

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