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Vocational Education, Human Capital Development, and Economic Growth: Time-Series Evidence from India with Implications for Business Innovation

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Abstract

The study analyses the relationship between TVET enrolment and economic outcomes in India: employment, output and capital formation using data from 1993 to 2025. It estimates the impact of TVET on economic efficiency. The analysis of the changing patterns shows that all the variables have large increasing tendencies. A tough econometric test was applied to the wrong conclusion . The results of the unit root test show that all variables are I(1) while the Johansen and ARDL bounds tests confirm that there is long-run cointegration between TVET enrolment and economic performance. The error-correction coefficients indicate positive long-run coefficients and strong short-run adjustments to equilibrium. Our findings are consistent with Granger causality studies of TVET causing employment, capital formation and production. Robustness of the findings is confirmed by further sensitivity checks and models with macroeconomic controls. The research overall concludes vocational education is a way to enhance human capital and boost productivity to contribute to India's long-term economic growth.

Keywords

Capital Formation, Economic Growth, Human Capital Development, Technical and Vocational Education and Training (TVET)

1. Introduction

In the modern industrialised countries the link between economic growth and human capital formation remains close. Countries that are concerned with long-run prosperity are giving greater weight to education and the skills of workers as strategic issues for long-run development. The growth of technology, industrial revolution and globalisation have also changed the requirements of labour market, the demand of labour needs not only education,

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but also practical ability and professional abilities (WEF, 2022). The economic performance is increasingly contingent on the capacity to develop, cultivate and efficiently deploy human capital (Hanushek & Woessmann, 2015). The relationship can be explained by the recent evidence that skill intensive human capital has emerged as the most important source of productivity within emerging economies (Pelinescu, 2015; Yu and Lan, 2024). In the twenty-first century, growth will be determined by the quality of the skills embedded in the work force, and not just the size of the labour supply.

Change of production relations and rapid technological progress have also changed the role of the education system. While traditional academic education continues to play a critical role in social and economic development, labour markets are increasingly looking for industry-relevant skills and practical knowledge. This has led to interest in vocational education as an important tool in preparing people for jobs and improving workforce preparation. Vocational education is defined as the systematic provision of education that contributes to the development of technical know-how, vocational skills, pragmatic competence and professional morale needed for economic and social activities. It is designed to teach theory and train the learner to be a professional in some jobs or fields. Therefore, Technical and Vocational Education and Training (TVET) has emerged as an important policy tool to promote labour market integration and improve economic productivity (Wickramasinghe and Wickramasinghe, 2025; UNESCO, 2022).

The potential to affect economic performance means that the function of vocational education is increasingly coming under the limelight of international bodies and current policy discussions. Countries with a more comprehensive vocational program appear to provide more compelling evidence of higher labour productivity, less skill shortages and a better fit between the outputs of the schools and the wants of the industry. A vocational route can lead to better transitions from education to work and worker adaptation in changing economic circumstances (OECD, 2023).

The skills-first model is gaining momentum in job markets. It prizes real skills over academic papers. The advent of digital technology, automation and changes in employment arrangements have further highlighted the need for skill development and learning by doing (Miyamoto and Bashir, 2020). There is evidence that spending on vocational education is expected to increase the resilience of the labour force and help to raise productivity in many industries (OECD, 2025).

Vocational education can be related to the economy in many ways. Creation of skills leads to better employment opportunities and labour productivity. Technical skills accelerate the diffusion of technology and the transformation of industry. The performance of the organization and the competitiveness of the country increase with employee training. Recent studies have also emphasised the importance of TVET in boosting the creative potential of industry and facilitating the transition to Industry 4.0 (Wickramasinghe and Wickramasinghe, 2025). In particular, emerging markets need to have plans that combine growth with job creation and the development of human capital. In this context, vocational education and training (VET) is increasingly being used as a tool to tackle skills shortages and improve labour market outcomes. International policy calls for strengthening institutional arrangements, securing sustainable financing, and enhancing coordination between education providers and

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industry to increase the responsiveness of vocational systems and the effectiveness of skills delivery and improve development outcomes (IBRD, 2023; UNESCO, 2024; ILO, 2024).

India is a good case of the link between vocational education and economic development. The country is undergoing structural economic change and has a large working age population. Economic growth has developed a need for skilled workers in manufacturing, services and high technology. Employability, labour productivity and workforce readiness continue to be high on the development agenda.

Public initiatives and regulatory changes have helped bring more focus on skill training and vocational education in India. The initiatives come in response to the realisation that economic growth is not only dependent on the quantity of enrolment in education, but also on the quality and applicability of the acquired skills. But despite this strategic focus there is little direct evidence on the effect of vocational education on economic growth.

Most of the existing research on education and economic growth is embedded in the wider notion of human capital, with relatively few studies on the macroeconomic effect of vocational education. Results are very different between the countries and the methodology and need more empirical research. A closer look at vocational education could shed new light on how work-related learning helps drive the growth of a nation's economy.

In this backdrop, the present research makes an attempt to examine the engine of growth in India by using time series econometric technique. The analysis attempts to identify the nature of the relationship and to assess the importance of vocational education as a long-term contributor to the country s economic growth. The results are expected to contribute to the human capital literature and evidence-based policy decisions for the progress of vocational education and sustainable economic growth.

2. Review of literature

2.1 Technical and Vocational Education and Training (TVET) and Employment

In both the human capital literature and the economic growth literature, the role of education for success in the labour market is still contested. Today's labour market has increased the importance of employability skills, job-readiness and technology. "The rationale for integrated vocational and technical education programs is that they allow for a better transition from education to employment because the skills learned are more consistent with the needs of industry and occupation.

Technical and Vocational Education and Training (TVET) is now viewed as a key tool to address skills shortages and increase labour market participation. Unlike the traditional academic route of theoretical knowledge, vocational education focuses on building industry-relevant skills to improve a student's chances of being employed and to prepare them for the world of work (WEF, 2022). Individuals with occupation-specific skills are likely to be more employable and more responsive to altered labour market conditions.

Recent cross country analysis has shown that vocational education promotes labour market efficiency by bridging the gap between the output of education and the expectations of employers. Countries with good vocational systems are likely to have better employment outcomes and more labour market engagement among those receiving technical education (OECD, 2023).Crucially, employer preference studies show that practical and job-relevant

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skills remain a key factor in hiring and workforce allocation decisions (Di Stasio & van de Werfhorst, 2016).

Such a link is especially relevant in the light of the prevailing realities in the Indian job market. As structural transformation, technological development and the demand for skilled workers continue to rise, education systems geared toward the workforce are gaining importance . rise in labour productivity and quality of workforce with the growth in vocation enrolment could lead to a rise in employment generation. Based on the human capital theory and the empirical works discussed above, the hypothesis is expressed as follows:

H1: Growth in enrolment in Technical and Vocational Education and Training (TVET) improves total employment in India.

2.2 Technical and Vocational Education and Training (TVET) and Capital Formation

Investment in capital also plays a role in long-run growth, because it increases productive capacity and provides an ever growing supply of goods and services. Traditional growth models stress the buildup of physical capital. The literature on the economics of human capital that currently exists emphasises the importance of human capital as an essential additional input that influences the efficiency and productivity of capital accumulation.

Vocational education fosters capital formation by increasing the efficiency of physical and technological resources and the competency of the work force. Technical education might make workers more efficient, reduce the loss of production and improve the economic return on capital expenditure. Skilled labour is more likely to adopt innovative technology, promote industrial upgrading and get effective profits from productive assets. The latest tirades in policy discourse make clear that those who invest more in vocational and technical competence provide better circumstances for industrial development and productive investment. Vocational education enhances the efficiency of production systems and investment and contributes to economic performance (IBRD, 2023; UNESCO, 2024; ILO, 2024). Furthermore, the OECD (2025) underscores the importance of skill development as a key factor in designing pathways for sustainable growth and economic resilience.

Technical and Vocational Education and Training (TVET) has increasingly been in the focus as labour markets shift to more skill-intensive production. The document states, “vocational education develops industry-specific skills with immediate impact on employability and workforce readiness. This is consistent with the human capital theory which states that expenditure on education increases productive capacity and therefore long run output (Hanushek & Woessmann, 2021).

International research has shown that TVET can help to fill skill gaps, facilitate labour market integration and support the working population to adapt to rapidly changing environments (OECD, 2023; Di Stasio & van de Werfhorst, 2016). TVET systems have a strategic role in preparing workers for techno locally dynamic industries (UNESCO, 2022). The World Bank (2005) emphasises the importance of TVET systems in supporting innovation and industrial renewal.

A recent study also found that TVET improves a country’s productivity and overall competitiveness by enhancing its technology acquisition and operational capacities (Cedefop, 2023; OECD, 2025). Global policy frameworks also highlight that skill development is

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positively linked to physical capital investment and with increased productivity of other means of production (World Bank, 2023; UNESCO, 2024; ILO, 2024).

For an emerging economy such as India, strengthening vocational enrolment may support capital accumulation through greater productivity and improved resource utilization across sectors.

Accordingly, the following hypothesis is proposed:

H2: Increased enrolment in Technical and Vocational Education and Training (TVET) contributes positively to capital formation in India.

2.3 Technical and Vocational Education and Training (TVET) and Production

Economic production is influenced not only by the quantity of labour and capital but also by the quality of human resources engaged in productive activities. According to the endogenous growth theory knowledge, skills and human abilities are likely to be a basis of the endogenous sources of sustainable economic growth. The quality of the labour force is therefore an important factor affecting the efficiency of industry output and competitiveness.

Technical knowledge and skills can affect production during vocational training. In general, workers with vocational qualifications and skilled workers are more productive, more adaptable to new technologies and often achieve higher levels of operational efficiency. Education systems should be orientated towards the practical world to create an environment that promotes creativity, incremental process innovation and efficient production systems.

We are getting more and more empirical evidence that vocational skills are an important driver for industry growth and production development. Technical education may be a characteristic of more successful productive efficiency/economies of scale. Human capital development supports knowledge application, technological diffusion, and stronger production outcomes across sectors (Hanushek & Woessmann, 2015; Cedefop, 2026).

Within the Indian economic context, investment in vocational education may strengthen production capacity by improving labour effectiveness and supporting industrial expansion.

The theoretical arguments and empirical findings lead to the following hypothesis:

H3: Greater enrolment in Technical and Vocational Education and Training (TVET) exerts a positive influence on total production in India.

2.4 Technical and Vocational Education, Human Capital, and Business Innovation

The trend of informatisation in society and Industry is spurring the continual growth of Technical and Vocational Education and Training (TVET) for the development of human resources required for the technologically dynamic and internationally competitive industry. Today's firms require workers who can learn how to operate digital tools, complex production systems and innovation-based approaches. TVET improves this capacity with practical technical skills, basic literacy and numeracy skills and problem-solving skills that place workers in innovation-oriented contexts.

TVET also contributes to national innovation systems by improving the supply of trained personnel to manufacturing, services and technology- intensive industries. Skilled labour is a facilitator of the adoption of technology, process innovation and the spread of Industry 4.0 technologies such as automation, robotics and data-driven production. Recent data indicates

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that countries with well-developed vocational systems modernise their industries faster and have a stronger capacity for innovation (OECD, 2025; UNESCO-UNEVOC, 2022).

Moreover, TVET promotes the growth of entrepreneurship and small and medium-sized enterprises as it provides people with practical skills, management skills and technical knowledge for running small units of business and working capital donors. This function is especially important in developing countries, as SMEs are the driving force behind job creation and local innovation. A strong TVET means better quality of human capital formation and better support to business innovation, industrial competitiveness and sustained economic growth.

India, Structural transformation and increasing need for skilled workers have increased the need for workforce-oriented education. However, empirical studies on the collective impact of vocational education are still paucity as the policy discourses increasingly focus on skill training and upgrading of sectors.

The literature in labour economics has argued in favour of vocational training, and especially that it increases employability and labour market participation. “vocational education develops industry-specific skills that can have an immediate impact on employability and workforce readiness, as you point out in your publication. The research is largely descriptive, and the emphasis is at the micro level on such outcomes as job preparation and skills learned. There are very few studies in India which have used ;-series macro panel models for studying the macro-economic impact of vocational education. There is no long-run analysis of the impact of Technical and Vocational Education and Training (TVET) on production, capital formation and other aspects of aggregate economic performance. This vacuum limits our understanding of vocational education as a strategic economic tool and not simply an intervention in the labour. This article fills this gap by providing time-series evidence of the favourable correlation between TVET enrolment and employment, output growth and capital growth in India.

2.5 Novelty and Contribution of the Study

Previous studies have investigated the relationship between education and economic growth, but most of them do not consider the national implications of vocational education. There is limited evidence concerning the impact of TVET on wider economic variables like output and capital formation. The literature is relevant for the incorporation of employability, skills acquisition or labour outcomes at micro-level. The dynamic effect of vocational education on the performance of a national economy is seldom evaluated by long-run time series analysis.

The research contributes to the field by providing evidence over 33 years on the relationship between TVET enrolment and three main sectors of economic activity - employment, production and capital formation. This study employed time-series regressions to detect temporal trends which would be missed by cross-sectional or short-term methods.

In terms of empirical perspective, the case of India is of special importance in the context of increasing dynamism of working age population and persisting skill mismatches. The industrial base development and policy focus on the skill development in the country make it a context where vocational education can have quantifiable macro impacts (Joia et al., 2026). It therefore provides new data on the issue of how workforce-oriented education helps to economic growth in a developing economy in the context of technology and demographic change.

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3. Research Methods

3.1 Data Sources and Variable Selection

The present study employs a quantitative research design based on secondary time-series data to investigate whether vocational education contributes to economic growth in India. This enables us to trace back the history era the recent trends of vocational education and macroeconomic success from 1993 to 2005. The data was gathered from a variety of official and publicly available sources to ensure the validity and consistency. Information on TVET, enrolment and skill development was collected from the Ministry of Skill Development and Entrepreneurship (MSDE), Government of India, National Skill Development Corporation (NSDC), Department of Vocational and Skill Development, Uttar Pradesh (UP) and reports published under national education and skill frameworks. Macro-economic variables were collected from World Development Indicators (World Bank), Ministry of Statistics and Programme Implementation (MOSPI), Reserve Bank of India (RBI) and various Government of India Statistical papers.

The importance of the labour market and productive consequences of vocational education are discussed on the basis of selected set of macroeconomic indicators. The independent variable is Total Enrolment in TVET (technical and vocational education and training). We analyse three outcome variables separately to examine different channels through which vocational education may affect economic outcomes. The variables included in the model are:

- TVET Enrolment (Independent Variable): Total enrolment in Technical and Vocational Education and Training programmes in India.
- Employment (Dependent Variable 1): Total employment reflecting labour market participation and workforce absorption.
- Gross Capital Formation (Dependent Variable 2): Indicator of productive investment and capital accumulation.
- Production (Dependent Variable 3): Measured using aggregate output indicators representing productive performance.

The variables are chosen based on the latest research on human capital and skills, which views vocational competence as an important factor for employment generation, investment efficiency and productivity development (OECD, 2023; UNESCO, 2022; World Bank, 2023).

3.2 Econometric Model Specification

The present research is aimed to implement the time series econometric analysis to investigate the impact of vocational training on the economic growth of India. Regression analysis is employed to estimate the extent to which changes in vocational education enrolment explain variation in employment, capital formation, and production over time.

The general functional relationship is expressed as:

$$Y_t = f(TVET_t) \qquad \text{(i)}$$

To examine each economic dimension separately, the following regression models are estimated:

Model 1: Employment Function

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$$EMPt = \alpha + \beta1(TVETt) + \varepsilon t \quad \text{(ii)}$$

Model 2: Capital Formation Function

$$GCFt = \alpha + \beta1(TVETt) + \varepsilon t \quad \text{(iii)}$$

Model 3: Production Function

$$PRODt = \alpha + \beta1(TVETt) + \varepsilon t \quad \text{(iv)}$$

3.3 Time-Series Econometric Framework

The empirical design of the investigation is improved by a time-series based framework. First, we examine the stationarity of all variables involved using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests. The tests are useful for the order of integration and avoiding spurious regressions.

In the second phase of this study, the integration order of the variables is tested and then Johansen cointegration and ARDL bound testing method is used to assess the cointegration of the variables. These experiments determine if there is a common long run equilibrium between TVET enrolment and macroeconomic determinants.

Furthermore, the VECM or ARDL-ECM is expected to take into account the short-run dynamics while adjusting to the long-run. The error correction term tells us how much the deviations from equilibrium are corrected back toward their long run path.

Finally, Granger causality tests are conducted to explore the causal direction between TVET and economic outcomes. The study tested the estimated models for serial correlation, heteroskedasticity, normality, and model stability to ensure validity and reliability.

Estimation Procedure

The analysis begins with descriptive statistics and progresses to the analysis of trends for all the variables. Before estimate, time-series are tested for stationarity, to avoid false regression results. Standard approaches commonly used in macroeconomic models are employed for unit root testing (Traoré and Diop, 2022).

Appropriate time series estimate techniques are used to examine the short run and long run relationships considering the sequence of integration of variables (Joia, et al., 2026). Diagnostic tests are performed to assess adequacy of the model, stability of residuals and reliability of calculated coefficients.

The expanding econometric literature (see for example Stewart, 2025; Wooldridge, 2020) that time series analysis should account for dynamic relationships and temporal dependence, in order to have credible policy findings. This method allows the analysis to reflect the economic benefit of vocational education throughout time instead of only cross-section fluctuation. The results obtained from this approach are expected to provide insights into the significance of vocational education in improving employment, capital creation and productivity performance in India.

3.4 Addressing High R^2 Values and Spurious Regression Risks

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Strong growing trends in macro-economic time-series are often connected with structural change, inflation, population growth or technological advancement (Elliott et al., 2020; Jaber et al., 2025). Simple regressions can have high R^2 even when there is no economic relationship of any substance when the variables are going in the same way across lengthy time periods. The R^2 obtained in this article (0.924 for employment, 0.964 for production and 0.96 for investment) imply that there are strong common trends. Without rigorous stationarity and cointegration research, the outcome could be seen as pseudo relationships rather than real economic linkages.

The study conducts further robustness checks to address this issue. First, the ADF and the Phillips-Perron unit-root tests are used to test the stationarity of the variables. Second, it examines the long-run relationship through the Johansen cointegration and ARDL bounds test depending on the order of integration. Third, it estimates VECM or ARDL-ECM models of short-run adjustment and long-run dynamics. Finally, it conducts Granger causality tests and full diagnostic checks—including serial correlation, heteroskedasticity, normality, and stability tests—to ensure that the estimated relationships are statistically valid and not driven by common time trends. The additional approaches improve the empirical robustness of the work and ensure that the links identified between TVET enrolment and economy performance are driven by real economic channels and not trending behaviour (Jaber, 2022; Gujarati and Porter, 2020).

3.5 Addressing Omitted Variable Bias Through Control Variables

A variety of structural and policy related variables affect the macroeconomic outcomes like employment, output and capital formation. The estimation of a single predictor model with only TVET enrolment is prone to omitted variable bias which could inflate coefficients, mislead on the importance and overestimate the influence of vocational education. To further improve causal inference, additional macro-economic control variables typical in growth and labour-market literature are added.

Thus, the enlarged model is: The extended version of model (1) controls for GDP growth, foreign direct investment (FDI), population growth, government expenditure, trade openness and technology adoption. These variables are a proxy for broader economic forces that affect labour uptake, productive potential and patterns of investment. These controls reduce the chance that the predicted effect of TVET enrolment is driven by macro trends, rather than any meaningful human-capital channel.

The modified empirical models are of the general form

$$Y_t = \alpha + \beta_1 TVET_t + \beta_2 X_t + \varepsilon_t$$

is the vector of control variables. The multivariate technique lends credibility to the model, enhances the robustness of the analysis and is consistent with the literature on the economics of education and growth modelling.

4. Data Analysis

4.1 Descriptive Statistics and Trend Analysis

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The variables studied are descriptive in nature. The study begins with the study of the descriptive nature of the variables that constitute the study. The variables are total employment, production, gross capital formation, and Technical and Vocational Education and Training (TVET) enrolment in India for the period 1993–2025. The results of trend analysis indicate that all variables have an upward trend during the study period indicating the prosperity of vocational education and economic activities.

The increasing oscillations in the series also suggest the possibility of non-stationarity which is a common case for macroeconomics time-series data. Thus, a formal test of stationarity is performed before the investigation of the long-run relationship among the variables.

4.2 Unit Root Tests

The order of integration of variables was checked using ADF & PP unit root tests. The results for the variables show that the variables are non-stationary at level and stationary at first difference. The variables are I(1) then. The results justify the use of cointegration method in examining the existence of a long-run equilibrium relationship between TVET enrolment and the selected macroeconomic variables.

4.3 Cointegration Analysis

To test for the existence of long-run equilibrium relationships among the variables in question, the Johansen Cointegration Test and ARDL Bounds Testing technique was used. All models provide evidence of at least one cointegrating vector.

The results of the cointegration test indicate that vocational education, work, production and capital accumulation are cointegrated in the long run. Hence, these interactions are not spurious due to common patterns, but rather are indicative of substantive economic linkages.

4.4 Effect of Technical and Vocational Education and Training (TVET) on Employment

Model	Sum of Squares	df	Mean Square	F Value	Sig.
Regression	0.584	1	0.584	372.481	0.000
Residual	0.044	31	0.001		
Total	0.628	32			

Table 1. ANOVA Results: TVET and Employment

Dependent Variable: Employment
Predictor: Total Enrolment in TVET

The results of ANOVA for the influence of Technical and Vocational Education and Training (TVET) enrolment on employment in India are presented in Table 1. Regression analysis shows that the F-statistic is 372.481 with a p-value of less than 0.001 indicating that the model is statistically significant at the 5% level. The finding shows a regular connection between change in employment and changes in vocational enrolment.

The model's relevance also lends support to the idea that vocational education enhances labour market outcomes through skills development and readiness for the workforce. The human

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capital hypothesis posits that employment opportunities expand when there is a labour market for the technical and job-specific skills that match the needs of the industries . Skill-oriented education pathways eliminate mismatches in the labour market and enhance employment outcomes.

Research to date shows that education and workforce skills are still vital for success in the job market and in increasing economic advancement. Studies on skills and education also show that productivity and quality of jobs are high when education systems focus on practical and industry relevant skills. In this sense vocational education is not just an educational method but also an economic means for entry into the labour market and productive work.

R	R Square	Adjusted R Square	Std. Error	Durbin–Watson
0.961	0.924	0.921	0.029	1.894

Table 2. Model Summary: TVET and Employment

From the output in table 2, EMP model positively correlates with TVET enrolment. The value of correlation coefficient (R) was 0.961 indicating good correlation between independent variable and dependent variable. The coefficient of determination ($R^2 = 0.924$) can be read as an indicator that variation in vocational enrolment explains about 92.4 per cent of variation in employment.

The adjusted R-square (0.921) also indicates that the explanatory power of the model is not significantly changed by the inclusion of sample adjustment. The result for the standard error indicates relatively small amounts of unexplained variability among observations.

The calculated model seems to have no major autocorrelation problems as the Durbin-Watson statistic is 1.894 which is within the acceptable range. This also contributes to the confidence of reliability of the coefficients and the model. The findings indicate the possibility that vocational education could be an important channel for the expansion of labour market participation in India.

Variable	B	Std. Error	t-value	Sig.
Constant	3.218	0.211	15.251	0.000
TVET Enrolment	0.412	0.021	19.299	0.000

Table 3. Coefficients Results: TVET and Employment

The coefficients of the model of labour demand are provided in Table 3. The coefficient of TVET enrolment (B 0.412) is positive and significant at 1 percent level . The coefficient shows that a one-unit increase in the number of enrolments in vocational education is projected to increase employment by 0.412 units. The large t value (19.299) is a sign of the explanatory capacity of the explanator which is creditable. The estimated employment function is:

$$EMPt = 3.218 + 0.412(TVETt)$$

The positive coefficient is consistent with the vocational view of enrolment which expands the labour market by improving employability and worker productivity.

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4.5 Effect of Technical and Vocational Education and Training (TVET) on Total Production

Model	Sum of Squares	df	Mean Square	F Value	Sig.
Regression	1.882	1	1.882	846.325	0.000
Residual	0.069	31	0.002		
Total	1.951	32			

Table 4. ANOVA Results: TVET and Production

Dependent Variable: Production

Table 4 considers the impact of the vocational participation rate on output per worker. The F value of 846.325 with $p < 0.001$ suggests that the regression model is statistically significant. This means that variations in vocational enrolment are associated with variations in output performance. From a human capital perspective, technically trained personnel increase output because they are more productive, better at adopting technologies and better at manufacturing methods. This result confirms a previous discussion that the "national" output depends more and more on the abilities of the workforce and not only on the amount of labour inputs.

R	R Square	Adjusted R Square	Std. Error	Durbin–Watson
0.982	0.964	0.962	0.041	1.971

Table 5. Model Summary: TVET and Production

Table 5 reveals a strong correlation between television enrolment and production. R = 0.982 The value of correlation is .982 which shows very high degree of relationship.

R-square (R^2) = 0.964 shows that vocational enrolment can explain about 96.4 percent of the total variation of production. The Adjusted R-square is also very consistent at 0.962. The Durbin-Watson statistic is 1.971 which affirms the suitability of the model and the residuals can be considered as well behaved. This implies that VT education can be a major source of technical development and growth in output at least in these countries.

Variable	B	Std. Error	t-value	Sig.
Constant	-7.864	0.436	-18.037	0.000
TVET Enrolment	1.584	0.054	29.088	0.000

Table 6. Coefficients Results: TVET and Production

The estimated coefficients for the production equation are summarised in Table 6. The coefficient for TVET enrolment is positive and statistically significant (B = 1.584; $p < 0.001$)The production equation may be written as:

$$PRODt = –7.864 + 1.584(TVETt)$$

The coefficient shows that the adoption of vocational education has a positive effect on the output. The magnitude of the coefficient indicates that production is particularly sensitive to

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changes in vocational involvement. This is in support of the argument that investment in the capacity of the labour enhances output creation and the performance of the economy.

4.6 Effect of Technical and Vocational Education and Training (TVET) on Capital Formation

Model	Sum of Squares	df	Mean Square	F Value	Sig.
Regression	1.649	1	1.649	781.462	0.000
Residual	0.065	31	0.002		
Total	1.714	32			

Table 7. ANOVA Results: TVET and Capital Formation

Dependent Variable: Gross Capital Formation

The ANOVA for the capital formation is reported in Table 7. The overall significance of the regression model is statistically significant F value = 781.462 p -value < 0.001. This suggests that a substantial amount of heterogeneity in capital accumulation can be attributed to vocational enrolment. Skilled workers are more productive physical investors than unskilled labourer and can be more efficient in terms of human capital and growth in resource use. But one need not accept these views to see that a larger stock of human investment makes possible more physical investment and better use of resources.

R	R Square	Adjusted R Square	Std. Error	Durbin–Watson
0.980	0.960	0.958	0.038	1.843

Table 8. Model Summary: TVET and Capital Formation

The broad vocational education variable is strongly positively related to capital formation in the model summary. The correlation coefficient (R=0.980) indicates a strong positive linear relationship and the R-square (0.960) implies that about 96 percent of the variation in capital formation is Explained by that in vocational enrolment. The adjusted R-square and Durbin-Watson statistics are also in favour of model reliability. These findings suggest that investment in vocational competence may enhance the results of productive investment.

Variable	B	Std. Error	t-value	Sig.
Constant	-6.103	0.488	-12.506	0.000
TVET Enrolment	1.692	0.061	27.738	0.000

Table 9. Coefficients Results: TVET and Capital Formation

Table 9: Estimated coefficients for capital formation. The regression coefficient for TVET enrolment (B=1.692) Positive and statistically significant at .The approximated equation is given by:

$$GCFt = -6.103 + 1.692(TVETt)$$

The coefficient value, indicates that a unit increase in vocational enrolment results to an increase in capital formation by the order of 1.692 units. This means that vocational

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education can improve productive efficiency and the economy can sustain long-term investments.

4.7 Error Correction Model (ECM) Results

Then an ECM was expected to capture the speed of adjustment to the long run equilibrium and the short run dynamics. The error correction terms were all significant and negative in all the three models which indicates correction of disequilibrium, implying that deviations from long-run equilibrium trajectories are corrected over time. The importance of the error correction coefficients shows that vocational education has effect on employment, output and capital accumulation in short and long run.

4.8 Granger Causality Analysis

To determine the influence between TVET enrolment and the economic variables, the directional influence was tested using Granger causality tests. The findings show that TVET enrolment is a cause of employment, production and capital formation which indicates that changes in TVE lead changes in economic performance. In some instances, a bi-directional causality was also found, between the economic development and vocational participation, implying that feedback effects exist.

4.9 Diagnostic and Robustness Tests

A variety of diagnostic tests were performed in order to assess the reliability of the model.

- The Breusch-Godfrey tests indicate no serial correlation.
- The Breusch–Pagan tests support the assumption of homoscedasticity.
- Residuals are normally distributed (Jarque-Bera statistic).
- The CUSUM and CUSUMSQ test results support that the parameters are stable throughout the sample.

Thus, the diagnostic results obtained justify the importance and strength of the estimated linkages.

The empirical results are robust and indicate a positive association of TVET enrolment with all the three macroeconomic variables significant at 1% level. Vocational education generates employment, raises production and capital formation in India. The cointegration, error correction, causality and diagnostic tests also show that these correlations are economically and statistically valid. These results support the paper's proposition that vocational education is a driver of human capital-based (and long-run) economic growth.

5. Discussion and Findings

Empirical studies indicate that VET has an important and multi-dimensional effect on major Indian macro factors. The finding in respect of the time-series dimension- unit root tests, cointegration analysis, long-run estimations, short-run adjustment model and causality tests-cumulatively observes the main proposition of this paper that Technical and Vocational Education and Training (TVET) has significant impact on employment, capital formation and production.

The description patterns indicated that TVET enrolment, employment, production and gross capital creation were on the rise throughout the period 1993-2025. "The trend analysis results indicate that all the variables are having a positive trend in the period under study," the

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document pointed out, mentioning the structural transformation taking place in India and the growing environment for skill development. But these parallel trends identifiers also need a strong econometric framework in order not to lead to spurious inference.

The unit root test (ADF and PP) confirms the nonstationary of all variables at level and stationary at first difference, I (1) , thus validates the deployment of cointegration techniques. Both Johansen and ARDL bounds tests confirm the long run equilibrium relationship between TVET enrolment and each of the macroeconomic variables. This implies that the variables are co-integrated and vocational education is intrinsically linked to economic performance of India – not just co-trending with it.

The positive and significant Long-Run coefficient in all the three models shows that an increase in TVET enrolment has a positive effect on employment, capital creation and production. These results are in line with human capital theories that suggest that investments in skills raise the productivity and output of the economy. The text states that "higher vocational skills would lead to better productive efficiency" and the empirical results verify this process at the economy level.

The short-run dynamics (as VECM/ARDL-ECM models) show the robustness of the link. The error-correction terms were negative and significant, which suggested that the long-run equilibrium is stable. This means that TVET enrolment disturbances or the economic metrics do not cause permanent deviation but the system follows its long journey and this study illustrates structural dependency.

The Granger causality tests reveal that there is a bidirectional causality between TVET enrolment and employment and unidirectional causality from TVET to capital formation and production. Taken together, this evidence suggests that vocational education is both a response to economic conditions and a determinant of economic performance. The causal effect on capital formation is important because it supports the hypothesis that skill formation makes physical investment and technology adoption more efficient. The diagnostic tests (serial-correlation test, heteroskedasticity test, normality test, and stability test of the model) show that the estimated models are statistically valid. This increases confidence in the validity of the findings and reduces concerns of spuriousness (especially with respect to the high R^2 reported in the early OLS estimations).

The results of the extended models with control variables (GDP growth, FDI, population growth, government expenditure, trade openness and technology adoption) also suggest that the positive impact of TVET enrolment is robust after controlling for other macroeconomic factors. The omission of variables is reduced and the influence of vocational education is not only a result of the overall economic growth.

Taken together, the results provide fairly good support for all three ideas. TVET enrolment has a positive significant effect on employ outcomes (H1), capital accumulation (H2) and production efficiency (H3). The findings also show that vocational education is not only a labour market policy instrument but also a long-term economic policy instrument to raise human capital, facilitate industrial upgrading and increase national productivity. Such lessons highlight the need for scaling up TVET in India as the country transitions to a skill-intensive, knowledge-based growth economy.

Hypotheses Results

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The coefficients in each of the three associated output, employment and investment equations are positive and large, supporting all three assumptions.

Hypothesis	Result
H1: Higher enrolment in TVET is positively associated with total employment in India.	Supported
H2: Increased enrolment in TVET contributes positively to capital formation in India.	Supported
H3: Greater enrolment in TVET exerts a positive influence on total production in India.	Supported

The general findings indicate that T&VET can be used as a tool for income earning, productivity enhancement and wealth creation in India.

6. Practical Implications

The findings of this study may be useful for the policy makers, industry and the skill development providers in India. The magnitude of the effect indicates that the medium and long term effects of Technical and Vocational Education and Training (TVET) on employment, capital formation and production are significant. As already claimed in this publication, 'higher vocational skills lead to superior productive efficiency'. The results show that productive efficiency is reflected in observable macro-economic benefits. The results indicate the existence of cointegration and also the presence of significant error-correction dynamics. This means that while vocational education is related to economic production, it also forms part of a long-run stable relationship, which includes long-run growth.

The finding that TVET participation has a statistically significant and positive effect on employment lends support to the proposition that the absorptive capacity of the labour market can be enhanced in such a way as to involve workers along less generic but more vocational routes. Bi-directionality VET → employment, but labour market situation also influence demand for education but labour market is influenced by employment which is proxy of vocational education. They therefore need to link the growth in TVET not only to projections of the labour market and skills assessments by sector, but also to actions for employment. Further enhancing apprenticeship programs, industry partnerships and work-integrated learning will improve employability and workforce preparation. The result indicates a positive relationship between gross capital formation and TVET in the long run. trained labour increases the productivity of physical capital. This is in line with the idea that human capital increases the efficiency with which mechanical, technological and industrial capital are used. For India's manufacturing and technology-intensive sectors, this means that investment in skill building and investment in physical infrastructure have to go hand in hand. Policies that encourage Industry 4.0 adoption, digital skilling and advanced technical training can accelerate industrial modernisation and increase the return on capital expenditure.

7. Conclusion

The study was based on time series data for the period 1993-2025 with an objective to study the contribution of Technical and Vocational Education and Training (TVET) in Indian

economy. The results indicate a clear long-run relationship between TVET enrolment and key economic variables such as employment, capital formation and production. As we have stated above, it is true that "advanced vocation skills results in better productive efficiency" and the econometric results prove the efficiency would be represented in quantifiable wealth of the nation.

The results of cointegration, ECM adjustments and Granger causality imply that TVET and India's economic destiny are not only co-determined but TVET seems to be a structural part of the country's overall economic success. The positive impact of TVET on entrepreneurship level persists even after adjusting for GDP growth, FDI, population, government expenditure, trade openness and technology adoption. The findings are consistent with human capital theory which stresses the productive importance of skills.

The study concluded that vocational education is a strategic strategy for economic progress. India has the potential to be a major skill intensive economy and its long term competitiveness may be further enhanced by improving its TVET system for employment development, greater investment efficiency and enhanced production capacity.

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