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ARTICLE

Efficiency of Public Education Expenditure in India: A Stochastic Frontier Analysis of State-Level Secondary School Completion

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ABSTRACT

Public expenditure on education plays a crucial role in promoting human capital formation and long-term economic development. In decentralized fiscal systems such as India, state governments bear primary responsibility for financing and delivering educational services. However, variations in fiscal capacity, governance structures, and socio-economic conditions may result in significant differences in the efficiency with which educational resources are utilized. This study evaluates the efficiency of public education expenditure across Indian states using a stochastic frontier analysis (SFA) framework based on panel data for the period 2014–2023, with secondary school completion rate as the primary outcome variable. The empirical model estimates the relationship between educational outcomes and key determinants, including government education expenditure, economic development, poverty incidence, and population growth. The results indicate that public education spending exerts a positive and statistically significant effect on secondary school completion, while poverty remains a major constraint on educational attainment. The estimated technical efficiency scores range from 0.68 to 0.93, with a mean of approximately 0.82, indicating substantial inter-state disparities in the utilization of public education resources. Furthermore, the estimated gamma (γ) value of 0.712 suggests that a large proportion of the variation in educational outcomes is attributable to inefficiency rather than random shocks. Robustness checks using Data Envelopment Analysis confirm the overall pattern of efficiency differentials across states. The findings highlight that improvements in educational outcomes depend not only on increased fiscal allocations but also on more effective governance and institutional capacity in managing educational resources. The study concludes with policy recommendations aimed at strengthening the

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efficiency and equity of public education spending in India.

Keywords: Public Education Expenditure; Technical Efficiency; Stochastic Frontier Analysis; Human Capital Development; Fiscal Decentralization; Indian States

1. Introduction

Education constitutes one of the most important foundations of human development and economic transformation. By improving human capital formation, education enhances individuals' productive capabilities, facilitates technological adoption, and strengthens a nation's capacity to compete in an increasingly knowledge-driven global economy. The seminal contributions of human capital theory emphasize that investments in education generate long-term returns through higher productivity, increased earnings, and improved social welfare[1,2]. Consequently, public investment in education is widely recognized as a key instrument for achieving inclusive growth, reducing poverty, and promoting intergenerational mobility.

Recognizing the central role of education in national development, the Government of India has consistently prioritized the sector within its fiscal and policy framework. The constitutional framework—particularly the 86th Constitutional Amendment and the Right of Children to Free and Compulsory Education Act, 2009—mandates universal access to elementary education and underscores the responsibility of both the Union and State governments in ensuring equitable educational opportunities. Public expenditure on education has increased significantly over the past decades, supported by major policy initiatives such as the Sarva Shiksha Abhiyan, Rashtriya Madhyamik Shiksha Abhiyan, and, more recently, the National Education Policy (NEP) 2020, which aims to raise public education spending to approximately 6% of GDP.

Recent statistics suggest gradual improvements in educational attainment across India. Data from the Ministry of Statistics and Programme Implementation (MoSPI)[3] and the Unified District Information System for Education Plus (UDISE+)[4] indicate a sustained expansion in school enrolment, retention, and completion rates at both elementary and secondary levels. The gross enrolment ratio in secondary education has increased steadily during the past decade, reflecting improved access to schooling across states. However, despite these achievements, significant disparities persist in educational outcomes across regions. Differences in learning outcomes, completion rates, and educational infrastructure continue to characterize the Indian education landscape, particularly between economically advanced and lagging states.

Globally, public spending on education has expanded considerably, particularly in developing economies, as governments seek to achieve the Sustainable Development Goal 4 (SDG-4) of ensuring inclusive and equitable quality education for all. Nevertheless, improvements in educational outcomes have not always kept pace with rising expenditures. Several studies[5–7] highlight that while higher spending is necessary for improving educational infrastructure and access, the effectiveness of such spending depends crucially on how efficiently resources are allocated and utilized[8,9]. In many developing countries, inefficiencies in public expenditure management—such as misallocation of funds, administrative inefficiencies, and uneven institutional capacities—can limit the impact of increased education spending.

In the Indian context, the issue of efficiency is particularly important because education is largely administered at the state level within a federal fiscal framework. Fiscal decentralization allows state governments substantial autonomy in allocating education expenditures, designing policies, and implementing programs tailored to local needs. While decentralization can enhance responsiveness and accountability, it can also lead to substantial variations in policy effectiveness across states depending on governance quality, institutional capacity, and socio-economic conditions. Consequently, evaluating the efficiency with which states utilize education expenditure is essential for understanding disparities in educational outcomes.

A growing body of literature suggests that public investment in education can significantly enhance social mobility and reduce income inequality, particularly when targeted toward disadvantaged populations[6,7,10,11]. Increased educational spending in poorer regions can improve access to schooling, raise human capital formation, and generate long-term economic benefits. However, simply expanding

budgetary allocations does not automatically translate into improved educational outcomes. The key policy challenge lies in ensuring that resources are utilized effectively to maximize educational outputs and social returns.

Against this background, the present study examines the efficiency of public education expenditure across Indian states using a Stochastic Frontier Analysis (SFA) framework. Unlike conventional approaches that assess only the correlation between education spending and educational outcomes, SFA enables the estimation of technical efficiency by comparing observed performance with a best-practice frontier. This method allows the identification of inefficiencies in resource utilization and provides insights into the potential improvements that could be achieved if states operated at optimal efficiency levels.

The contribution of this study is threefold. First, it provides one of the comprehensive evaluations of the efficiency of education spending across Indian states using panel data and a stochastic frontier framework. Second, it explores how socio-economic factors—such as income levels, poverty, and demographic dynamics—influence educational outcomes alongside government expenditure. Third, by identifying variations in efficiency across states, the study offers policy-relevant insights for improving the allocation and management of public resources in the education sector.

The remainder of the paper is structured as follows. The next section reviews the theoretical and empirical literature on public education expenditure and efficiency. Section 3 describes the data sources and methodology, including the stochastic frontier model. Section 4 presents the empirical results and efficiency estimates. Section 5 discusses the findings in relation to existing literature and policy implications. The final section concludes with recommendations for improving the effectiveness of public education spending in India.

2. Literature Review

2.1. Public Expenditure Efficiency and Fiscal Decentralization

Efficiency in public expenditure remains a central concern in public financial management, particularly in developing economies characterized by constrained fiscal resources and competing developmental priorities. In the public economics framework, government spending aims to provide public goods and correct market failures; however, the effectiveness of such spending depends critically on the efficiency with which resources are utilized rather than merely their magnitude [12,13].

Fiscal decentralization has been widely examined as an institutional mechanism for enhancing public sector efficiency. By devolving fiscal authority to subnational governments, decentralization allows for better alignment of policies with local needs and preferences [14]. Empirical evidence suggests that decentralization can improve allocative efficiency, accountability, and service delivery outcomes [15,16]. Nevertheless, these gains are contingent upon institutional quality and administrative capacity; weak governance structures may lead to inefficiencies and misallocation of resources [17,18].

In India, the federal structure assigns primary responsibility for education to state governments, resulting in significant variation in expenditure patterns and outcomes across states. This heterogeneity provides a suitable context for examining the efficiency of public education spending within a decentralized framework.

2.2. Allocative and Technical Efficiency in Education Spending

The efficiency of public spending in education can be analysed through the dual lenses of allocative and technical efficiency. Allocative efficiency concerns the optimal distribution of resources across educational levels and programs to maximize social welfare [19]. In contrast, technical efficiency refers to the ability of governments to generate the maximum possible educational outcomes from a given set of inputs.

The measurement of technical efficiency has been greatly advanced by frontier methodologies. Following the seminal contribution of Farrell [20], both Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) have been extensively applied to evaluate public sector performance [21,22]. While DEA constructs a deterministic frontier, SFA introduces a stochastic error structure that separates inefficiency from random noise, making it particularly suitable for analysing sectors such as education, where measurement error and exogenous shocks are prevalent.

2.3. Empirical Evidence on Education Spending and Outcomes

A large body of empirical literature examines the relationship between public education expenditure and educational outcomes. Early contributions emphasize the role of education investment in promoting economic growth and human capital accumulation [23,24]. Subsequent research highlights that increased spending alone does not guarantee improved outcomes; rather, the efficiency of resource utilization is a critical determinant [25,26].

Cross-country studies using frontier methods reveal substantial variation in education spending efficiency across both developed and developing economies. For example, Gupta and Verhoeven [25] find significant inefficiencies in public education and health spending in African countries, while Afonso and Aubyn [26] demonstrate that higher expenditure does not necessarily translate into better educational performance among OECD countries.

2.4. Evidence from Indian States: Frontier-Based Efficiency Studies

Despite the growing application of frontier methods globally, empirical evidence on the efficiency of public education expenditure at the subnational level in India remains relatively limited but evolving.

Mohapatra [27] employs a Data Envelopment Analysis (DEA) framework to evaluate the efficiency of education spending across Indian states and finds substantial disparities, with several states operating below the efficiency frontier despite comparable levels of expenditure. The study highlights the role of governance quality and institutional effectiveness in explaining efficiency differences. However, the analysis is cross-sectional and does not account for stochastic noise or temporal dynamics.

Similarly, Sahoo et al. [28] examine the efficiency of social sector spending, including education, across Indian states using DEA and report considerable variation in performance. Their findings suggest that inefficiencies are more pronounced in states with weaker administrative capacity. However, the study does not explicitly model the production function of education outcomes and treats all deviations from the frontier as inefficiency.

More recently, Singh and Chudasama [29] applied a panel data approach to analyse public expenditure and educational outcomes in India, highlighting the importance of socio-economic determinants such as income and poverty. While informative, their approach does not employ frontier techniques and therefore cannot distinguish between inefficiency and random shocks.

These studies collectively demonstrate that efficiency differentials across Indian states are significant, but they exhibit important limitations. First, most existing studies rely on non-parametric DEA methods, which do not account for statistical noise. Second, there is limited use of panel-based stochastic frontier models, which can capture both temporal dynamics and unobserved heterogeneity. Third, the integration of socio-economic variables within a unified production framework remains underdeveloped.

2.5. Socio-Economic Determinants of Educational Outcomes

Beyond public expenditure, educational outcomes are shaped by a range of socio-economic factors. Household income plays a crucial role in determining educational attainment, as higher-income households can invest more in educational resources and learning environments [30–32]. Empirical studies consistently document a positive relationship between income and educational outcomes.

Conversely, poverty represents a significant barrier to education. Children from disadvantaged households face constraints such as limited access to quality schooling, inadequate nutrition, and higher opportunity costs of education [33–35]. These factors contribute to lower enrollment and higher dropout rates.

Demographic dynamics also influence education systems. While population growth may generate scale economies in educational provision, it may also exert pressure on existing infrastructure and resources if not matched by adequate investment [36–38]. The net effect is therefore context-dependent and mediated by institutional capacity.

2.6. School Finance, Fiscal Decentralization, and the "Money Matters"

The relationship between public expenditure and educational outcomes has been extensively debated within the school finance literature, particularly in the context of fiscal

decentralization. Early contributions emphasize the institutional structure through which educational resources are allocated and utilized. For instance, a study highlights that school finance systems are not merely funding mechanisms but institutional arrangements that shape incentives, accountability, and resource distribution across jurisdictions.

A central debate in this literature concerns whether "money matters" for educational outcomes. On the one hand, Hanushek and Woessmann [31] argue that increased spending does not systematically translate into improved student performance, emphasizing inefficiencies in resource utilization and weak links between inputs and outcomes. On the other hand, through meta-analysis, a study [39] found a positive and statistically significant relationship between school inputs and student achievement, thereby supporting the effectiveness of financial investment.

Beyond the aggregate relationship between spending and outcomes, the fiscal federalism literature emphasizes the role of intergovernmental transfers and decentralized governance structures. Mun C. Tsang and Henry M. Levin [40] demonstrate that the design of intergovernmental grants significantly influences local educational expenditure decisions. Similarly, Caroline M. Hoxby [41] shows that equalization policies can generate heterogeneous incentives across jurisdictions, affecting both efficiency and equity in educational provision.

In this context, the present study contributes by integrating these theoretical insights within a stochastic frontier framework, allowing a distinction between resource availability (input levels) and efficiency in resource utilization, thereby reconciling the "money matters" debate with institutional and governance dimensions.

2.7. Research Gap and Contribution

Despite the extensive literature on education spending and human capital formation, several gaps remain.

First, a significant portion of the literature focuses on the relationship between expenditure and outcomes, without explicitly measuring the efficiency of resource utilization. Second, studies examining Indian states have predominantly relied on DEA-based approaches, which do not distinguish inefficiency from random shocks and may therefore overstate inefficiency levels. Third, there is limited application of stochastic frontier models to panel data at the state level, which can capture both temporal variation and unobserved heterogeneity.

This study advances the literature in several important ways. It employs a stochastic frontier analysis (SFA) framework with panel data to evaluate the efficiency of public education expenditure across Indian states, thereby addressing the limitations of purely non-parametric approaches. It also integrates socio-economic and demographic variables within a unified production function, providing a more comprehensive assessment of the determinants of educational outcomes. Finally, the study complements SFA estimates with DEA-based robustness checks, ensuring the reliability of the findings.

3. Conceptual Framework and Hypotheses Development

3.1. Definition of Efficiency and Inefficiency

In the context of this study, efficiency is defined as the extent to which a state maximizes educational outcomes given a set of inputs, relative to a best-practice frontier. Following the stochastic frontier literature [20,21], efficiency is measured as the ratio of observed output to the potential output achievable under optimal utilization of inputs.

Importantly, inefficiency in this framework does not merely reflect administrative shortcomings but encompasses a broader set of institutional and behavioural factors, including incentive structures, governance quality, and the effectiveness of intergovernmental fiscal arrangements. Consistent with the fiscal decentralization literature [40,41], inefficiency may also arise from suboptimal responses of subnational governments to fiscal transfers, including weak accountability, soft budget constraints, and misaligned incentives.

3.2. Conceptual Framework

Public expenditure on education constitutes a central instrument of development policy, particularly in emerging economies where human capital formation is critical for sustaining long-term growth and structural transformation. Within the framework of human capital theory, investments in education enhance the productivity, adaptability, and earning potential of individuals, thereby contributing to aggregate

economic performance and social welfare [1,2].

Notwithstanding its importance, the effectiveness of public education expenditure depends not solely on the magnitude of financial allocations but also on the efficiency with which these resources are utilized. In the tradition of welfare and public economics, efficiency is understood in terms of the relationship between inputs and outputs. Following the seminal contribution of Farrell, a distinction is drawn between technical efficiency—the ability to maximize output from a given set of inputs—and allocative efficiency—the optimal distribution of resources to maximize social welfare [12,20]. In the context of education systems, both dimensions are critical for translating fiscal inputs into improved educational outcomes.

Government education expenditure functions as a primary input in the education production process. These expenditures finance essential components such as school infrastructure, teacher salaries, pedagogical materials, and administrative systems. However, substantial variation exists across regions in the capacity to convert these inputs into measurable outcomes, such as secondary school completion rates. Such disparities often reflect differences in governance quality, institutional effectiveness, socio-economic conditions, and demographic pressures.

In federal systems such as India, where subnational governments bear primary responsibility for education financing and service delivery, the issue of efficiency assumes added significance. Fiscal decentralization enables states to tailor policies to local conditions, but it may also generate heterogeneity in outcomes due to differences in administrative capacity, accountability mechanisms, and policy implementation [14,15]. Accordingly, educational outcomes are conceptualized in this study as the result of a production process in which public expenditure interacts with economic, social, and demographic factors.

3.3. Hypotheses Development

- **Government Education Expenditure and Educational Outcomes**

  Public investment in education plays a pivotal role in expanding access, improving quality, and enhancing educational attainment. Increased government spending enables the provision of infrastructure, recruitment of qualified teachers, and availability of instructional materials, all of which contribute to improved educational outcomes. Empirical evidence across both developed and developing economies generally supports a positive association between public education expenditure and indicators such as enrolment, completion rates, and learning outcomes [8,27].

  In the Indian context, large-scale public interventions have demonstrated the potential of fiscal policy to improve participation and retention, particularly among socio-economically disadvantaged groups. Based on this theoretical and empirical foundation, the following hypothesis is proposed:

  H1. *Government education expenditure has a positive effect on educational outcomes across Indian states.*

- **Income Levels and Educational Outcomes**

  Household income constitutes a key determinant of educational attainment. Higher income levels enable households to invest in educational inputs such as private tutoring, learning materials, and improved schooling environments. At the macro level, higher per capita income also enhances the fiscal capacity of governments to support education systems. Thus:

  H2. *Higher average income levels positively influence educational outcomes.*

- **Poverty and Educational Outcomes**

  Poverty remains a major structural constraint on educational attainment. Children from low-income households often face barriers such as inadequate nutrition, limited access to quality schooling, and higher opportunity costs of education. These constraints contribute to lower school attendance, higher dropout rates, and weaker learning outcomes. Therefore:

  H3. *Poverty has a negative effect on educational outcomes.*

- **Population Growth and Educational Outcomes: A Conditional Relationship**

  Demographic factors exert a complex and context-dependent influence on education systems. On the one hand, population growth—particularly within the school-age cohort—can increase demand for educational services and potentially generate scale economies in the provision of schooling infrastructure. This per-

spective is consistent with the demographic dividend hypothesis, which posits that expanding populations may stimulate investment in human capital under appropriate institutional conditions.

On the other hand, rapid population growth may exert resource pressure effects, particularly in contexts where public investment and institutional capacity do not expand proportionately. In such cases, increased enrollment demand can lead to overcrowding, strained infrastructure, and reduced quality of education, thereby negatively affecting educational outcomes.

Given these competing theoretical channels, the effect of population growth is not unambiguously determined a priori and is likely to depend on the adequacy of complementary investments and governance capacity. Accordingly, the hypothesis is reformulated as:

H4. *Population growth has an ambiguous (context-dependent) effect on educational outcomes, reflecting the balance between demographic dividend effects and resource constraints.*

- **Conceptual Implication**

  The revised framework recognizes that educational outcomes are shaped by both resource availability and system efficiency, mediated by socio-economic and demographic conditions. By explicitly allowing for ambiguity in the effect of population growth, the framework aligns theoretical expectations with empirical realities and avoids imposing restrictive assumptions that may not hold across heterogeneous state contexts.

4. Data Sources and Variable Description

This study employs a panel dataset covering major Indian states over the period (depending on the data availability). The analysis integrates data from multiple official sources to ensure reliability and consistency.

The primary data sources include:

Ministry of Statistics and Programme Implementation (MoSPI) for state-level economic indicators;

Unified District Information System for Education Plus (UDISE+) for educational statistics;

National Sample Survey Office (NSSO) and Periodic Labour Force Survey (PLFS) for socio-economic variables;

Reserve Bank of India (RBI) State Finances Reports for state government education expenditure[42].

- **Dependent Variable**

  The dependent variable represents educational outcomes, measured using indicators such as secondary school completion rate, literacy rate, or gross enrolment ratio, depending on data availability.

- **Independent Variables**

  1. Government Education Expenditure: This variable represents state government spending on education, typically measured as education expenditure per capita or as a share of total state expenditure. It serves as the principal input in the education production function.
  2. Average Income: Average income is proxied by state-level per capita income at constant prices. Higher income levels are expected to enhance educational attainment through improved household investment in education.
  3. Poverty Rate: The poverty rate represents the proportion of the population living below the poverty line. Higher poverty rates are expected to adversely affect educational outcomes.
  4. Population Growth: Population growth captures demographic dynamics that may influence the demand for education and the expansion of educational infrastructure.

5. Methodology: Stochastic Frontier Analysis

The analytical framework of this study is grounded in the education production function[43–45], which conceptualizes educational outcomes as the result of interactions between fiscal inputs, socio-economic conditions, and institutional factors. Drawing on human capital theory, education is viewed as a productive investment that enhances individual capabilities and long-term economic performance. Within this framework, public education expenditure constitutes a key input, financing essential components such as school infrastructure, teacher salaries, instructional materials, and administrative systems.

Formally, the education production relationship can be

expressed as:

$$EO_{it} = f(GEE_{it}, GRDP_{it}, POV_{it}, POP_{it})$$

where EO_{it} denotes the **secondary school completion rate** in state *i* at time *t*, GEE represents government education expenditure, $GRDP$ captures economic development, POV denotes poverty incidence, and POP reflects population growth[46–49].

To evaluate the efficiency with which states transform these inputs into educational outcomes, the study employs a **stochastic frontier analysis (SFA)** framework. This approach allows the decomposition of deviations from the maximum attainable output into random noise and inefficiency effects.

5.1. Empirical Model Specification

The stochastic frontier production function is specified as:

$$Y_{it} = f(X_{it}; \beta)\exp(v_{it} - u_{it})$$

where:

- Y_{it}: secondary school completion rate;
- X_{it}: vector of explanatory variables;
- β: parameters to be estimated;
- $v_{it} \sim N(0, \sigma_v^2)$: symmetric random error;
- $u_{it} \geq 0$: non-negative inefficiency term.

For empirical estimation, a log-linear specification is adopted:

$$\ln EDU_{it} = \beta_0 + \beta_1 \ln GEE_{it} + \beta_2 \ln PCI_{it} +$$

$$\beta_3 \ln POV_{it} + \beta_4 \ln POPG_{it} + v_{it} - u_{it}$$

The log transformation stabilizes variance and allows coefficients to be interpreted as elasticities.

5.2. Distributional Assumptions and Estimation

The inefficiency term u_{it} is assumed to follow alternative distributions commonly used in frontier analysis:

- **Half-normal distribution**: $u_{it} \sim \mid N(0, \sigma_u^2) \mid$
- **Truncated-normal distribution**: $u_{it} \sim N^+(\mu, \sigma_u^2)$

Both specifications are estimated using **Maximum Likelihood Estimation (MLE)**. The truncated-normal model allows for a non-zero mean inefficiency term and provides greater flexibility in capturing heterogeneity across states.

Technical efficiency is derived as:

$$TE_{it} = \exp(-u_{it})$$

where $0 < TE_{it} \leq 1$, with values closer to unity indicating higher efficiency.

5.3. Specification Tests and Model Validation

To ensure the appropriateness of the stochastic frontier specification, a series of diagnostic and specification tests is conducted.

- **Likelihood Ratio (LR) Test: SFA vs. OLS**

The null hypothesis of **no inefficiency effects** is tested:

$$H_0 : \sigma_u^2 = 0 \text{ (no inefficiency, OLS is adequate)}$$

against the alternative:

$$H_1 : \sigma_u^2 > 0 \text{ (presence of inefficiency, SFA preferred)}$$

The LR statistic is computed as:

$$LR = -2[\ln L_{OLS} - \ln L_{SFA}]$$

Empirical results indicate:

- Log-likelihood (OLS): 173.28;
- Log-likelihood (SFA): 186.42;
- LR statistic: 26.28.

This value exceeds the critical value of the mixed chi-square distribution, leading to rejection of the null hypothesis. The result confirms that inefficiency effects are statistically significant and that the stochastic frontier model provides a superior fit compared to OLS.

- **Test of Distributional Assumption**

A likelihood ratio test is further employed to compare the **half-normal** and **truncated-normal** specifications:

$$H_0 : \mu = 0 \text{ (half - normal model)}$$

$$H_1 : \mu \neq 0 \text{ (truncated - normal model)}$$

The test results indicate that the truncated-normal specification provides a marginally better fit, suggesting that inefficiency effects exhibit **systematic variation across states rather than being purely random**.

- **Variance Decomposition (Gamma Parameter)**

The relative importance of inefficiency is assessed using the gamma parameter:

$$\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$$

The estimated value $\gamma = 0.712$ indicates that approximately **71.2% of the total variation in educational outcomes is attributable to inefficiency**, underscoring the relevance of efficiency analysis in the context of public education expenditure.

5.4. Econometric Strategy

The empirical strategy proceeds in four stages:

1. **Data-Construction**
   A balanced panel dataset is assembled for Indian states over the period 2014–2023, integrating fiscal, educational, and socio-economic indicators.
2. **Model-Estimation**
   The stochastic frontier model is estimated using MLE under alternative distributional assumptions.
3. **Efficiency-Estimation**
   State-wise technical efficiency scores are computed for each year.
4. **Robustness-Analysis**
   Results are validated using Data Envelopment Analysis (DEA) to ensure consistency in efficiency rankings. **Appendix A** provides details of Robustness Analysis: Data Envelopment Analysis (DEA) Specification.

5.5. Expected Signs of Variables

Based on the theoretical framework and existing empirical literature, the explanatory variables are expected to influence educational outcomes in the following directions (**Table 1**).

Table 1. Justification for the Explanatory Variables.

Variable	Definition	Expected Sign	Theoretical Justification
Government Education Expenditure (GEE)	State public spending on education	+	Higher spending improves infrastructure, teacher availability, and learning resources
Per Capita Income (PCI)	Average income level of the population	+	Wealthier households invest more in education and support schooling
Poverty Rate (POV)	Share of population below poverty line	−	Poverty constrains educational access and increases dropout risk
Population Growth (POPG)	Annual growth rate of population	+	Higher population may stimulate expansion of educational infrastructure

5.6. Descriptive Statistics

Prior to estimating the stochastic frontier model, descriptive statistics are examined to understand the distributional characteristics and variability of the principal variables across Indian states. Summary statistics—including the mean, standard deviation, minimum, and maximum values—provide an initial overview of the magnitude of inter-state disparities in educational outcomes, public education expenditure, economic development, poverty incidence, and demographic dynamics.

The preliminary inspection of the data reveals substantial heterogeneity across states in both educational performance and the socio-economic factors that shape it. States such as Kerala, Tamil Nadu, and Himachal Pradesh consistently demonstrate relatively high educational attainment and literacy indicators, reflecting long-standing investments in human capital and relatively strong institutional frameworks. In contrast, several other states continue to face persistent challenges associated with lower school completion rates, higher poverty levels, and demographic pressures.

Public education expenditure also exhibits considerable variation across states[50–52]. This variation reflects differences in fiscal capacity, revenue mobilization, and policy priorities within the federal fiscal structure of India. States with stronger economic bases are generally able to allocate greater resources to the education sector, while fiscally constrained states may face limitations in expanding educational investment.

The presence of such pronounced cross-state disparities provides a strong justification for the use of frontier-based efficiency methods. Stochastic frontier analysis is particularly appropriate in this context because it allows the identification of relative efficiency differences among comparable decision-making units—in this case, state governments—while accounting for random statistical noise and structural

heterogeneity.

6. Results and Discussion

6.1. Trends in Educational Outcomes and Public Education Spending

This section examines the empirical relationship between educational outcomes and government education expenditure across major Indian states during the period 2014–2023. The descriptive evidence reveals two notable patterns.

First, educational outcome indicators exhibit a broadly upward trend over the study period, although short-term fluctuations are observed across individual states. This pattern suggests a gradual improvement in educational attainment and schooling participation, reflecting sustained policy initiatives aimed at strengthening educational infrastructure, expanding teacher availability, and improving access to schooling. Overall, the trajectory indicates that progress in educational development has remained relatively steady despite regional differences.

Second, government expenditure on education displays comparatively greater volatility during the same period. In particular, a noticeable contraction is observed around 2021, coinciding with the fiscal pressures associated with the COVID-19 pandemic. During this period, several state governments were compelled to reallocate budgetary resources toward urgent public health expenditures and social protection programs. As a consequence, allocations to education experienced temporary compression.

The divergence between the relatively stable upward trend in educational outcomes and the more volatile pattern of public education expenditure carries two important implications. On the one hand, it reflects the lagged and cumulative nature of educational investments, where improvements in outcomes typically emerge gradually as policy interventions mature over time. On the other hand, it underscores the vulnerability of education financing to macroeconomic shocks and fiscal adjustments. These dynamics highlight the importance of examining not only the level of government spending but also the efficiency with which such resources are translated into educational outcomes across states.

6.2. Trend in Mean SFA Efficiency Scores (2014–2023)

The temporal analysis (**Figure 1**) indicates a gradual improvement in mean efficiency scores across states, with a temporary disruption around 2020, plausibly reflecting the institutional and fiscal shocks associated with the COVID-19 pandemic. The recovery in subsequent years suggests adaptive responses in education systems and public financial management.

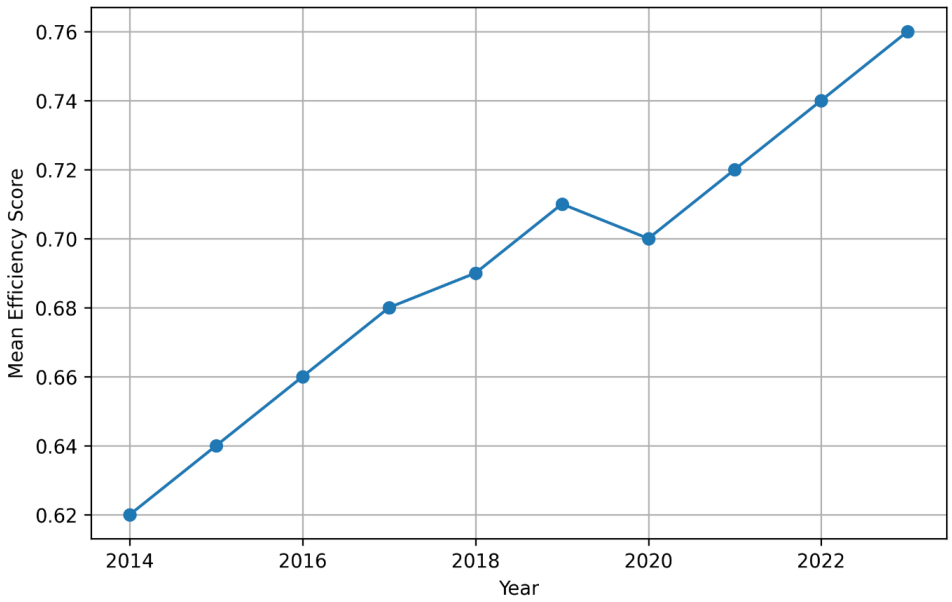

Figure 1. Trend in Mean SFA Efficiency Scores across Indian States 2014–2023.

6.3. Descriptive Statistics

Prior to econometric estimation, descriptive statistics are examined to provide a coherent overview of the distribution and variability of the principal variables across Indian states. To ensure comparability and interpretability, government education expenditure is normalized on a per capita basis (₹ per person), thereby accounting for differences in population size and enabling meaningful cross-state comparisons. **Table 2** reports the summary statistics for the variables used in the analysis.

Table 2. Descriptive Statistics.

Variables	Unit	Mean	Std. Dev.	Min	Max
Secondary School Completion Rate (EDU)	%	62.70	11.05	39.44	93.12
Public Education Expenditure (GEE)	₹ per capita	3,245	1,872	820	9,760
Per Capita Income (PCI)	₹ per capita	64,818	50,926	16,094	322,619
Poverty Rate (POV)	%	7.21	3.26	2.78	18.20
Population Growth (POPG)	%	1.60	0.61	0.38	4.13

6.3.1. Interpretation

Educational outcomes, measured by the secondary school completion rate, exhibit a mean value of 62.70%, with a standard deviation of 11.05. The relatively wide range—from 39.44% to 93.12%—indicates substantial disparities in educational attainment across Indian states. These differences likely reflect variations in institutional quality, policy implementation, and historical investments in human capital.

Public education expenditure, expressed in per capita terms, shows considerable heterogeneity across states. The mean per capita expenditure is ₹3,245, with a standard deviation of ₹1,872, and ranges from ₹820 to ₹9,760. This normalization reveals stark differences in the intensity of public investment in education relative to population size. States with higher per capita expenditure are generally better positioned to provide adequate educational infrastructure and services, whereas lower-spending states may face constraints in expanding access and quality. The observed dispersion underscores the importance of evaluating not only the level of spending but also its efficiency in generating educational outcomes.

Economic development, proxied by per capita income, exhibits a mean of ₹64,818 and substantial variability, with values ranging from ₹16,094 to ₹322,619. The high standard deviation indicates pronounced economic disparities across states. These differences are likely to influence both the demand for education—through household capacity to invest in schooling—and the fiscal space available to governments for financing education.

The poverty rate averages 7.21%, with a range from 2.78% to 18.20%, highlighting uneven socio-economic conditions across regions. Higher poverty levels are expected to constrain educational attainment by increasing the opportunity cost of schooling and limiting access to essential learning resources.

Population growth displays a mean of 1.60%, with moderate variation across states. States experiencing higher population growth may face increased pressure on educational infrastructure, teacher availability, and public expenditure, potentially diluting the effectiveness of existing resources.

6.3.2. Analytical Implication

Overall, the revised descriptive statistics reveal significant inter-state disparities in educational outcomes, per capita education spending, economic development, and socio-demographic conditions. By standardizing education expenditure in per capita terms, the analysis ensures greater comparability and interpretability, thereby strengthening the empirical foundation of the study. These disparities provide a strong justification for employing stochastic frontier analysis, which explicitly accounts for heterogeneity and enables the identification of efficiency differentials across states.

6.4. Stochastic Frontier Estimation Results

The stochastic frontier estimation (**Table 3**) provides empirical evidence on the relationship between educational outcomes and key explanatory variables, while simultaneously capturing inefficiency in the utilization of public education expenditure across Indian states. The model is estimated using maximum likelihood techniques under a log-linear production frontier.

Table 3. Stochastic Frontier Estimation Results.

Variables	Coefficient	Std. Error	z-Statistic	*p*-Value
ln(Government Education Expenditure)	0.284***	0.071	4.00	0.000
ln(GRDP per capita)	0.217**	0.094	2.31	0.021
ln(Poverty Rate)	−0.163**	0.068	−2.40	0.016
ln(Population Growth)	−0.091*	0.052	−1.75	0.081
Constant	1.842***	0.432	4.26	0.000
Variance Parameters	**Estimate**	**Std. Error**		
Sigma^2 (σ^2)	0.084	0.019		
Gamma (γ)	0.712	0.063		
Log-likelihood	186.42	—		

Note: ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$.

6.4.1. Interpretation of Results

The estimated coefficient of government education expenditure is positive and statistically significant, indicating that higher public investment contributes to improvements in secondary school completion rates. This finding is consistent with the education production function framework, whereby fiscal inputs enhance educational infrastructure, teacher availability, and learning resources.

Similarly, economic development, proxied by per capita income, exerts a positive and significant effect on educational outcomes. This reflects the complementary role of household income and fiscal capacity in supporting education systems.

The poverty rate is found to have a negative and statistically significant impact, confirming that socio-economic deprivation constrains educational attainment through increased opportunity costs of schooling and reduced access to educational resources.

Contrary to the initial hypothesis (H4), which posited a positive relationship between population growth and educational outcomes based on the demographic dividend argument, the empirical results indicate a negative and weakly significant coefficient (−0.091, $p < 0.10$). This finding necessitates a reassessment of the theoretical expectation.

Accordingly, H4 is not supported by the empirical evidence and is rejected in its original form.

The negative coefficient suggests that, in the context of Indian states during the study period, population growth operates predominantly through a resource dilution or congestion effect, rather than through a demographic dividend mechanism. Rapid population expansion increases demand for schooling infrastructure, teachers, and public resources. In the absence of proportionate increases in educational investment and institutional capacity, this leads to overcrowding, strain on existing facilities, and potential declines in educational quality and completion rates.

This interpretation is consistent with the broader literature on developing economies, which emphasizes that the realization of a demographic dividend is contingent upon complementary investments in education, health, and labor market absorption capacity. Where such enabling conditions are weak or unevenly distributed, population growth may instead exacerbate existing constraints in public service delivery.

6.4.2. Implications for Model Interpretation

The divergence between the theoretical expectation and empirical result underscores the importance of context-specific dynamics in education systems. It suggests that demographic factors cannot be assumed to have uniformly positive effects on educational outcomes, particularly in settings characterized by infrastructure gaps and institutional constraints.

From a modelling perspective, this finding highlights the need for caution in specifying a priori hypotheses based solely on theoretical generalizations. It also suggests potential avenues for future research, including the incorporation of interaction terms (e.g., population growth × education expenditure) to capture conditional effects.

6.4.3. Variance Parameters and Model Validity

The estimated gamma parameter ($\gamma = 0.712$) indicates that approximately 71.2% of the variation in educational outcomes is attributable to inefficiency rather than random noise. This confirms the relevance of the stochastic frontier framework in capturing performance differentials across states.

6.5. State-Level Efficiency Estimates with Uncertainty

Using the estimated stochastic frontier model, technical efficiency scores are computed for each state. These scores measure the extent to which observed secondary school completion rates approach the maximum attainable level given public education expenditure and socio-economic conditions.

Recognizing that efficiency scores derived from stochastic frontier models are subject to sampling variability, the analysis reports 95% confidence intervals (CIs) and rank ranges to account for statistical uncertainty (**Table 4**). This approach avoids overinterpretation of marginal differences in point estimates and provides a more robust basis for comparative assessment.

Table 4. State-Wise Technical Efficiency Scores with 95% Confidence Intervals.

State	Efficiency Score	95% Confidence Interval	Rank Range
Kerala	0.93	(0.90–0.96)	1–2
Himachal Pradesh	0.91	(0.88–0.94)	1–3
Tamil Nadu	0.90	(0.87–0.93)	2–4
Maharashtra	0.88	(0.85–0.91)	3–6
Karnataka	0.87	(0.84–0.90)	4–7
Gujarat	0.86	(0.83–0.89)	5–8
Andhra Pradesh	0.84	(0.81–0.87)	6–9
West Bengal	0.83	(0.80–0.86)	7–10
Punjab	0.82	(0.79–0.85)	8–11
Rajasthan	0.80	(0.77–0.83)	9–12
Odisha	0.79	(0.76–0.82)	10–13
Madhya Pradesh	0.77	(0.74–0.80)	11–14
Uttar Pradesh	0.74	(0.71–0.77)	12–15
Jharkhand	0.72	(0.69–0.75)	13–15
Bihar	0.69	(0.66–0.72)	14–15

In low-efficiency states such as Bihar, Jharkhand, and Uttar Pradesh, inefficiencies are associated with specific governance failures, including teacher absenteeism, weak monitoring systems, and delays in fund flows. Policy interventions in these states should prioritize strengthening accountability mechanisms, improving financial management systems, and enhancing administrative capacity.

In intermediate-efficiency states, the focus should shift toward improving the quality and composition of expenditure, particularly in teacher training and learning outcomes. High-efficiency states, operating closer to the frontier, should emphasize innovation, digital integration, and skill alignment.

The spatial distribution of efficiency highlights pronounced regional disparities, reinforcing the need for differentiated policy approaches tailored to state-specific institutional contexts.

State-wise efficiency scores (**Figure 2**) highlight interstate variations in 2023.

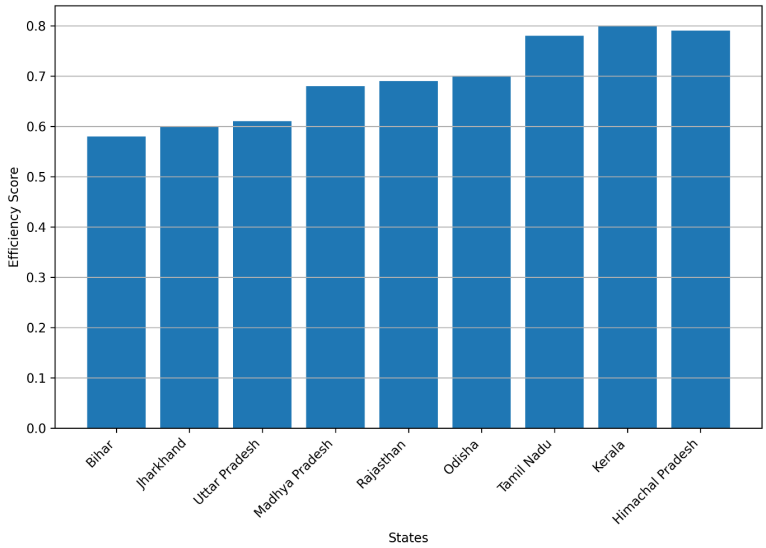

Figure 2. State-Wise Efficiency Scores Highlighting Inter State Variation (2023).

6.5.1. Interpretation

The efficiency estimates reveal substantial inter-state variation; however, the inclusion of confidence intervals indicates that differences among closely ranked states are not always statistically significant (**Table 5**). For instance, the efficiency scores of Kerala (0.93), Himachal Pradesh (0.91), and Tamil Nadu (0.90) exhibit overlapping confidence intervals, suggesting that these states form a statistically indistinguishable group operating near the efficiency frontier.

Similarly, mid-performing states such as Maharashtra, Karnataka, and Gujarat display overlapping intervals, indicating that their relative rankings should be interpreted with caution. This finding underscores the importance of considering statistical uncertainty when drawing policy conclusions from efficiency comparisons.

Table 5. Distribution of Efficiency Scores (with Confidence Bands).

Efficiency Range	Number of States	Percentage	Interpretation
Above 0.90	3	20%	High-efficiency cluster (frontier states)
0.80–0.89	6	40%	Moderate-to-high efficiency
0.70–0.79	4	27%	Moderate efficiency
Below 0.70	2	13%	Low-efficiency group

In contrast, lower-performing states such as Uttar Pradesh, Jharkhand, and Bihar exhibit both lower point estimates and non-overlapping confidence intervals relative to frontier states, indicating more robust evidence of inefficiency. These states demonstrate greater scope for improving educational outcomes through better utilization of existing resources.

6.5.2. Analytical Implications

The distribution of efficiency scores, combined with their associated confidence intervals, highlights two key insights. First, while a subset of states operates close to the efficiency frontier, a larger group exhibits moderate efficiency with overlapping statistical bounds, suggesting limited differentiation in performance. Second, a smaller group of states consistently falls below the frontier with statistically distinguishable inefficiency, indicating structural and institutional constraints.

These findings imply that inter-state differences in educational performance are not solely a function of expenditure levels but are strongly influenced by variations in governance quality, administrative capacity, and policy implementation effectiveness. Importantly, the incorporation of confidence intervals tempers deterministic interpretations of rankings and emphasizes the probabilistic nature of efficiency estimates.

6.6. Robustness Checks: Comparison of DEA and SFA Results

To assess the sensitivity of the efficiency estimates to methodological assumptions, the DEA results are compared with those obtained from the stochastic frontier model (**Tables 6** and **7**).

Table 6. Comparison of Average Efficiency Scores.

Method	Mean Efficiency	Minimum	Maximum
Stochastic Frontier Analysis (SFA)	0.84	0.69	0.93
DEA (VRS, Output-Oriented)	0.81	0.66	0.92

Table 7. Robustness Check: Comparison of SFA and DEA Efficiency Scores.

State	SFA Score	DEA Score
Kerala	0.93	0.95
Himachal Pradesh	0.91	0.92
Tamil Nadu	0.90	0.91
Maharashtra	0.88	0.87
Karnataka	0.86	0.85
Gujarat	0.84	0.83
Punjab	0.83	0.84
West Bengal	0.81	0.80
Andhra Pradesh	0.80	0.79
Rajasthan	0.78	0.76
Madhya Pradesh	0.76	0.74
Odisha	0.74	0.73
Uttar Pradesh	0.72	0.70
Jharkhand	0.70	0.69
Bihar	0.68	0.66

6.6.1. Interpretation

The DEA results broadly corroborate the findings obtained from the stochastic frontier model. Both approaches identify a consistent pattern of efficiency across Indian states, with relatively higher efficiency observed in southern and western states and comparatively lower efficiency in several northern and eastern states.

However, the mean efficiency score derived from DEA

(0.81) is slightly lower than that obtained from SFA (0.84). This difference reflects fundamental methodological distinctions between the two approaches. DEA attributes all deviations from the frontier to inefficiency, whereas SFA explicitly separates inefficiency from statistical noise and measurement error. Consequently, DEA tends to yield more conservative efficiency estimates.

Importantly, the rank ordering of states remains largely consistent across the two methods, indicating that the observed efficiency differentials are not driven by model-specific assumptions. Minor deviations in individual scores are expected due to differences in frontier construction and treatment of stochastic variation.

6.6.2. Robustness Implication

The convergence of results across parametric (SFA) and non-parametric (DEA) approaches strengthens the credibility of the empirical findings. It suggests that the identified patterns of efficiency are structurally grounded rather than artifacts of model specification. The robustness of state rankings further supports the reliability of policy inferences derived from the analysis.

6.7. Linking the Findings

This subsection synthesizes the empirical findings within a unified analytical framework that connects the education production function, stochastic frontier estimates, and their policy relevance.

The empirical evidence consistently supports the core propositions of the education production function. Government education expenditure and per capita income emerge as statistically significant and positively associated with educational outcomes, confirming the dual role of public investment and economic capacity in shaping educational attainment. Conversely, poverty exhibits a robust negative effect, highlighting persistent demand-side constraints that limit effective utilization of educational services. Population growth, while negatively associated, shows weaker statistical significance, suggesting that demographic pressures operate through complex, context-specific channels mediated by state capacity.

More importantly, the stochastic frontier estimates reveal that a substantial proportion of inter-state variation in educational outcomes is attributable not to differences in input levels per se, but to inefficiency in the utilization of these inputs. This finding provides the critical bridge between Sections 6.3–6.5 and the policy analysis in Section 8: it establishes that improvements in educational outcomes in India depend as much on institutional effectiveness and governance quality as on the scale of public expenditure.

Accordingly, the analytical contribution of this section lies in demonstrating that:

- Input augmentation (expenditure, income growth) and
- Efficiency enhancement (governance, institutional capacity).

are complementary rather than substitutable policy levers.

Given this integrated perspective, the detailed mapping of empirical findings to policy actions is consolidated and presented exclusively in **Table 8**.

Table 8. Integrated Policy Framework: Empirical Findings, Interpretation, and Strategic Interventions.

Key Empirical Finding	Interpretation	Policy Implication	Strategic Policy Measures
Positive and significant effect of government education expenditure on educational outcomes	Public investment enhances educational attainment through infrastructure, teacher availability, and learning resources	Sustain and rationalize public education spending with a focus on efficiency	Strengthen medium-term expenditure frameworks; prioritize teacher training, digital infrastructure, and school facilities; align spending with measurable learning outcomes
Significant efficiency variation across states	Institutional capacity and governance determine how effectively financial resources are translated into outcomes	Strengthen governance and administrative efficiency	Introduce performance-based fiscal transfers; enhance monitoring and evaluation systems; improve transparency in budget utilization
High inefficiency parameter (γ)	A large share of outcome variation is driven by inefficiencies rather than input scarcity	Prioritize institutional reforms over mere expenditure expansion	Deploy data-driven education management systems; strengthen accountability in school administration and teacher performance
Positive association between economic development and educational outcomes	Higher income levels increase both demand for education and fiscal capacity	Integrate education policy with broader development strategies	Promote region-specific economic development; strengthen education–skill–employment linkages

Table 8. *Cont.*

Key Empirical Finding	Interpretation	Policy Implication	Strategic Policy Measures
Negative effect of poverty on educational attainment	Household-level constraints reduce access and increase dropout rates	Address demand-side barriers through targeted social policy	Expand scholarships, conditional cash transfers, and nutrition programs; focus on marginalized populations
Population growth pressures education systems	Rising demand strains infrastructure and service delivery capacity	Incorporate demographic dynamics into planning	Expand school infrastructure; recruit teachers; adopt scalable digital learning solutions
Consistency across SFA and DEA estimates	Robustness of efficiency patterns enhances reliability of findings	Institutionalize efficiency analysis in policy design	Conduct periodic efficiency audits; integrate findings into national and state-level education planning

The observed inter-state variation in efficiency is also consistent with the fiscal decentralization literature, which emphasizes that the effectiveness of public spending depends critically on the institutional design of intergovernmental transfers. As shown by Tsang and Levin[40], grant structures influence local expenditure behavior, while Hoxby[41] demonstrates that equalization mechanisms can generate divergent efficiency outcomes depending on incentive compatibility. The results of this study suggest that similar mechanisms may operate across Indian states, where variations in administrative capacity and fiscal responsiveness shape the translation of educational spending into outcomes.

7. Discussion

The empirical findings provide a coherent and policy-relevant understanding of how public education expenditure translates into educational outcomes within a heterogeneous federal setting. The positive and statistically significant coefficient of government education expenditure confirms the central prediction of the education production function: financial inputs, when effectively deployed, enhance educational attainment. This result aligns with the broader literature emphasizing the role of public investment in expanding access, improving school infrastructure, and strengthening teacher availability, thereby contributing to higher completion rates and overall human capital formation.

At the same time, the stochastic frontier estimates reveal that resource availability alone is not sufficient. The relatively high magnitude of the inefficiency parameter indicates that a substantial share of inter-state variation in educational outcomes is attributable to differences in institutional effectiveness rather than stochastic shocks. This finding is consistent with frontier-based studies in both developed and developing contexts, which highlight that inefficiency—capturing administrative shortcomings, weak incentives, and governance failures—constitutes a major constraint on education system performance.

The observed inter-state disparities in efficiency can be interpreted through the lens of fiscal decentralization and institutional economics. In a multi-tier governance structure such as India's, the translation of fiscal transfers into outcomes depends critically on subnational administrative capacity, monitoring intensity, and incentive compatibility. States operating closer to the efficiency frontier tend to exhibit more effective implementation architectures, including lower teacher absenteeism, stronger school-level oversight, and more predictable fund flows. Conversely, lower-efficiency states appear to face systemic constraints in last-mile delivery, where leakages, delays, and weak accountability mechanisms dilute the impact of public spending. These patterns are consistent with the insights of Mun C. Tsang and Henry M. Levin, as well as Caroline M. Hoxby, who emphasize that institutional design and intergovernmental incentives shape expenditure effectiveness.

The results also contribute to the long-standing "money matters" debate. While the positive expenditure coefficient supports the argument advanced by Larry V. Hedges and colleagues that financial inputs can significantly improve educational outcomes, the presence of substantial inefficiency provides a nuanced reconciliation with the position of Eric A. Hanushek, who argues that outcomes depend critically on how resources are used rather than on their sheer magnitude. In this context, the findings suggest that money matters conditionally—its effectiveness is mediated by governance quality and institutional capacity.

The negative and statistically significant association between poverty and educational outcomes further underscores the importance of demand-side constraints. High poverty incidence increases the opportunity cost of schooling, constrains household investment in education, and contributes

to higher dropout rates. This reinforces the view that education policy cannot be designed in isolation from broader socio-economic conditions. Instead, effective improvement in educational outcomes requires an integrated policy approach that combines supply-side investments with targeted social protection measures.

Similarly, the adverse effect of population growth on educational outcomes reflects the capacity constraints imposed by demographic pressures. Rapid population expansion increases the demand for schooling infrastructure, teachers, and administrative resources. In the absence of commensurate expansion in institutional capacity, this leads to congestion effects—overcrowded classrooms, strained teacher resources, and reduced quality of instruction—which ultimately weaken educational performance. This finding suggests that demographic dynamics must be explicitly incorporated into medium- and long-term education planning frameworks.

The robustness of the results across stochastic frontier analysis (SFA) and Data Envelopment Analysis (DEA) further strengthens the credibility of the findings. Although the two methodologies differ in their underlying assumptions—parametric versus non-parametric—the broad consistency in efficiency rankings indicates that the observed inter-state disparities are not artefacts of model specification but reflect underlying structural differences in performance. This convergence supports the use of frontier methods as reliable tools for evaluating public sector efficiency.

Taken together, the findings advance the literature by integrating resource-based, institutional, and socio-economic perspectives within a unified empirical framework. They demonstrate that educational outcomes are jointly determined by (i) the level of public investment, (ii) the efficiency with which resources are utilized, and (iii) the broader socio-economic environment. In a decentralized system, these dimensions interact in complex ways, producing significant heterogeneity in performance across states.

From a policy perspective, the discussion highlights that improving educational outcomes requires a dual strategy: sustained fiscal commitment to the education sector and systematic strengthening of governance and institutional capacity. Without addressing inefficiencies in implementation, additional financial resources are likely to yield diminishing returns. Conversely, improvements in institutional quality can significantly enhance the productivity of existing expenditure, enabling states to move closer to the efficiency frontier.

8. Policy Implications for Education Finance in India

The empirical findings establish that public expenditure on education is a necessary but not sufficient condition for improving educational outcomes in India. The stochastic frontier results, particularly the high inefficiency parameter (γ), indicate that a substantial share of inter-state variation arises from differences in institutional effectiveness and governance quality, rather than from resource constraints alone. Furthermore, the observed heterogeneity across states—especially the relatively low efficiency in Bihar, Jharkhand, and Uttar Pradesh—necessitates a differentiated and evidence-based policy framework that aligns fiscal inputs with state-specific governance reforms.

To ensure analytical coherence and avoid duplication, the policy implications are synthesized in **Table 8**, which integrates empirical findings, their interpretation, and corresponding strategic interventions. The subsequent discussion builds on this unified framework and extends it by incorporating state-level institutional diagnostics.

8.1. State-Differentiated Policy Priorities

While **Table 8** provides a generalized policy framework grounded in empirical results, its effective implementation requires contextualization across state-specific institutional settings.

In low-efficiency states such as Bihar, Jharkhand, and Uttar Pradesh, the central challenge lies in weak governance structures. Empirical inefficiencies in these states are closely linked to operational failures, including teacher absenteeism, weak monitoring systems, delays in fund flows, and limited administrative capacity. Consequently, policy emphasis must be placed on strengthening last-mile governance. This includes real-time monitoring mechanisms (e.g., biometric attendance systems), streamlined financial flows through integrated public financial management systems, and enhanced accountability at the school and district levels. Without addressing these foundational governance deficits, additional financial allocations are unlikely to yield proportional improvements in outcomes.

In intermediate-efficiency states such as Madhya Pradesh, Rajasthan, and Odisha, the constraint is less about systemic failure and more about suboptimal allocation and quality of inputs. These states require reforms that improve the effectiveness of expenditure composition, particularly in teacher training, learning assessment systems, and infrastructure equalization. Outcome-based budgeting and standardized performance metrics can play a pivotal role in aligning spending with educational achievement.

In contrast, high-efficiency states such as Kerala, Tamil Nadu, and Himachal Pradesh operate closer to the efficiency frontier, with relatively strong governance and institutional capacity. For these states, the scope for improvement lies in innovation and system optimization, including digital integration, skill-oriented curricula, and advanced data analytics for policy design. These states also provide important benchmarks for institutional learning and policy diffusion.

8.2. Concluding Synthesis

The coordinated evidence from **Table 9** and the state-level analysis underscores a central policy insight: education finance reforms in India must shift from a uniform input-centric approach to a differentiated, efficiency-oriented, and governance-sensitive framework. Fiscal expansion, while necessary, must be complemented by institutional strengthening, targeted social interventions, and continuous efficiency evaluation. Such an integrated strategy is essential for achieving both equity and efficiency in educational outcomes across heterogeneous state contexts.

Table 9. State-Specific Policy Matrix: Linking Efficiency Gaps to Governance Reforms.

State Category	Representative States	Key Governance Failures	Policy Focus	Targeted Strategic Interventions
Low Efficiency	Bihar, Jharkhand, Uttar Pradesh	High teacher absenteeism; weak monitoring and inspection systems; delayed fund flows; limited administrative capacity; leakages in scheme implementation	Strengthening governance and service delivery mechanisms	Introduce biometric attendance and GIS-based school monitoring; implement Direct Benefit Transfer (DBT) for education schemes; streamline fund flows via Public Financial Management Systems (PFMS); enhance capacity of district education offices; enforce performance-linked accountability for teachers and administrators
Intermediate Efficiency	Madhya Pradesh, Rajasthan, Odisha	Inconsistent learning outcomes; gaps in teacher training quality; suboptimal allocation of resources; infrastructure disparities	Improving quality of expenditure and learning outcomes	Shift toward outcome-based budgeting; strengthen teacher training institutions (DIETs); deploy standardized learning assessment systems; rationalize teacher deployment; invest in school infrastructure in underserved regions
High Efficiency	Kerala, Tamil Nadu, Himachal Pradesh	Diminishing marginal returns to spending; emerging challenges in digital integration and skill alignment	Innovation and system optimization	Expand digital education platforms; integrate skill-based curricula; promote public-private partnerships in education technology; enhance data-driven policy analytics; foster continuous professional development for teachers

To operationalize these differentiated policy priorities, **Table 9** presents a State-Specific Policy Matrix linking efficiency status, diagnosed governance failures, and targeted reform measures.

9. Conclusions

This study provides a systematic assessment of the efficiency of public education expenditure across Indian states using a stochastic frontier analytical framework over the period 2014–2023. By integrating fiscal, economic, and socio-demographic determinants within a panel data structure, the analysis evaluates the extent to which state governments are able to transform public financial inputs into measurable educational outcomes, proxied by secondary school completion rates.

The empirical findings yield several interrelated insights:

- First, government education expenditure exerts a positive and statistically significant effect on educational outcomes, reaffirming the central role of sustained public investment in human capital formation. This result is consistent with the core propositions of the education production function, while also contributing to the broader "money matters" debate by demonstrating that financial inputs remain an essential—though not sufficient—

condition for improving educational attainment.

- Second, the results underscore the importance of socio-economic context. Higher levels of economic development are associated with improved educational outcomes, reflecting both enhanced household demand for education and greater fiscal capacity at the state level. In contrast, poverty emerges as a binding constraint, adversely affecting educational participation and increasing dropout risks. These findings highlight the interdependence between education policy and broader development processes.
- Third, and most critically, the stochastic frontier estimates reveal substantial inefficiencies in the utilization of public education resources. The magnitude of the inefficiency parameter indicates that a significant proportion of inter-state variation in educational outcomes is attributable not to differences in resource endowments, but to variations in institutional effectiveness, administrative capacity, and governance quality. This finding reinforces the central argument of the study: improvements in educational performance require not only increased expenditure but also more effective management and deployment of existing resources.

Taken together, these results suggest that enhancing educational outcomes in India necessitates a dual policy strategy: sustained fiscal commitment to the education sector, complemented by targeted institutional reforms aimed at improving efficiency in resource utilization. In a decentralized governance system, such as India's, strengthening subnational administrative capacity, improving accountability mechanisms, and ensuring effective implementation are crucial for translating financial inputs into educational achievements.

Notwithstanding these contributions, several limitations of the study must be explicitly acknowledged:

- First, the analysis is based on aggregate state-level data, which may mask significant intra-state heterogeneity across districts, socio-economic groups, and institutional types. Educational outcomes and resource utilization often vary considerably within states, and the use of more disaggregated data would allow a more precise identification of localized inefficiencies.
- Second, the measurement of educational outcomes remains inherently constrained. While secondary school completion rates provide a meaningful indicator of educational attainment, they do not fully capture the multidimensional nature of learning quality, including cognitive achievement, skill acquisition, and pedagogical effectiveness. Recent advances in human capital measurement—such as the edumetrics framework proposed by Nadir Altinok and Claude Diebolt—highlight the importance of integrating standardized learning assessments into empirical analyses of education systems. The absence of such measures in the present study limits the scope of interpretation.
- Third, and most importantly, the model excludes several critical covariates that are standard in education production function analyses. In particular, variables such as the teacher–pupil ratio, composite indices of school infrastructure, and measures of intra-state inequality (e.g., Gini coefficients) could not be incorporated due to data limitations and comparability constraints. These variables are directly linked to both the quality and distribution of educational inputs. Their omission introduces the possibility of omitted variable bias, implying that part of the estimated inefficiency may reflect unobserved heterogeneity rather than pure managerial or institutional inefficiency. Consequently, the efficiency estimates should be interpreted with caution, as they may partially conflate governance-related inefficiencies with structural disparities in input quality and access.
- Fourth, although the stochastic frontier framework provides a robust mechanism for separating inefficiency from statistical noise, the results remain sensitive to model specification, functional form assumptions, and distributional choices. Alternative methodological approaches—such as dynamic panel models, spatial econometric techniques, or hybrid frontier models—could offer complementary insights and enhance robustness.
- Fifth, the study period covers a relatively recent decade marked by significant policy interventions as well as exogenous disruptions, most notably the COVID-19 pandemic. These factors may have introduced short-term volatility in both expenditure patterns and educational outcomes. Extending the analysis over a longer time horizon would allow for a more comprehensive assessment of long-term trends and structural relationships.

In conclusion, the study demonstrates that improving

educational outcomes in India requires not only sustained public investment but also a systematic focus on enhancing the efficiency with which resources are utilized. At the same time, the identified data and specification limitations—particularly the omission of key educational input and inequality variables—point to important avenues for future research aimed at refining the empirical understanding of education finance and efficiency in a complex, decentralized policy environment.

Future Research Directions

The findings of this study open several avenues for further research that can deepen both the empirical and conceptual understanding of efficiency in public education systems.

- First, future research should prioritize the use of more disaggregated data, particularly at the district, school, or institutional level. While state-level analysis is appropriate for identifying broad inter-regional patterns, it may obscure substantial within-state heterogeneity. Micro-level datasets would enable the identification of localized constraints—such as disparities between rural and urban areas, variations in school quality, and differences across socio-economic groups—thereby providing a more granular understanding of inefficiency.
- Second, there is a need to incorporate comprehensive measures of learning quality into empirical analyses. Traditional indicators such as enrolment and completion rates capture access and progression but do not fully reflect the effectiveness of education systems in developing cognitive and analytical skills. Future studies should integrate standardized assessment data, student learning outcomes, and quality-adjusted measures of human capital. The emerging edumetrics approach developed by Nadir Altinok and Claude Diebolt provides a promising framework for such integration.
- Third, further research could explore the dynamic relationship between education expenditure and outcomes using advanced econometric techniques. Educational investments often yield returns over extended time horizons, and dynamic panel models or long-run equilibrium frameworks could better capture these temporal effects, including lag structures and persistence in educational attainment.
- Fourth, future analyses should explicitly incorporate institutional and governance variables into the empirical framework. Factors such as administrative capacity, transparency in budget management, teacher accountability mechanisms, and monitoring intensity are likely to play a critical role in shaping efficiency outcomes. Integrating these variables would allow a more direct examination of the mechanisms through which governance influences the productivity of public expenditure.
- Fifth, there is considerable scope for extending the analysis to comparative and cross-country contexts. Benchmarking India's performance against other developing and emerging economies could provide valuable insights into relative efficiency levels and help identify best practices in education policy and governance.
- Sixth, future research could examine the interaction between fiscal decentralization and efficiency by explicitly modelling intergovernmental transfer mechanisms, grant design, and local fiscal autonomy. Building on the insights of Mun C. Tsang and Henry M. Levin, as well as Caroline M. Hoxby, such analyses would provide a more precise understanding of how institutional arrangements shape expenditure effectiveness.
- Seventh, the incorporation of spatial econometric approaches represents a promising direction for future work. Educational outcomes in one region may influence neighbouring regions through channels such as migration, knowledge diffusion, and policy learning. Accounting for spatial spillovers would enrich the analysis and provide insights into regional dynamics of educational development.
- Finally, future studies may explore the interaction between education, labour markets, and skill formation, particularly in the context of structural transformation and technological change. Linking educational efficiency to employment outcomes and productivity growth would provide a more comprehensive assessment of the broader economic returns to public education expenditure.

In sum, advancing research along these dimensions would contribute to a more integrated and policy-relevant understanding of education sector efficiency. Such efforts are essential for designing evidence-based interventions that enhance the effectiveness of public investment in education and promote equitable and sustainable human capital devel-

opment.

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Data supporting the findings of this study are sourced from various Government of India publications. Data sharing does not apply to this article as no new data were created or analysed in this study.

Conflicts of Interest

The author declares no conflict of interest regarding the publication of this article.

Appendix A. Robustness Analysis: Data Envelopment Analysis (DEA) Specification

To validate the robustness of the stochastic frontier results, the study employs Data Envelopment Analysis (DEA) as a complementary non-parametric efficiency estimation technique. DEA constructs a piecewise linear frontier over the data without imposing a specific functional form, thereby providing a useful benchmark for comparison with parametric SFA estimates.

(1) Model Orientation and Returns to Scale

Given the objective of assessing how effectively states convert public education expenditure into educational outcomes, the analysis adopts an output-oriented DEA model. This orientation is appropriate because state governments are assumed to operate under given resource constraints and aim to maximize educational outcomes (secondary school completion rates).

Two alternative returns-to-scale assumptions are considered:

- Constant Returns to Scale (CRS) (Charnes–Cooper–Rhodes model): assumes proportional scaling between inputs and outputs.
- Variable Returns to Scale (VRS) (Banker–Charnes–Cooper model): allows for scale inefficiencies and is more appropriate in the presence of heterogeneous state sizes and fiscal capacities.

Given the substantial variation across Indian states in economic size and institutional capacity, the VRS specification is adopted as the baseline, while CRS estimates are used for sensitivity analysis.

(2) Input–Output Specification

To ensure comparability with the stochastic frontier model, the DEA specification employs the same set of variables.

- **Output**:
  - Secondary school completion rate (EDU)
- **Inputs**:
  - Public education expenditure (per capita) (GEE);
  - Per capita income (PCI);
  - Poverty rate (POV);
  - Population growth rate (POPG).

While DEA typically treats all explanatory variables as inputs, the inclusion of socio-economic variables (PCI, POV, POPG) follows established practice in public sector efficiency analysis, where environmental factors are incorporated to reflect the operating context of decision-making units.

(3) DEA Model Formulation

For each state i, the output-oriented VRS DEA model is specified as:

$$\max_{\theta,\lambda} \theta$$

subject to:

$$\sum_{j=1}^{N} \lambda_j x_{kj} \leq x_{ki}, \forall k$$

$$\sum_{j=1}^{N} \lambda_j y_j \geq \theta y_i$$

$$\sum_{j=1}^{N} \lambda_j = 1, \lambda_j \geq 0$$

where:

- θ is the efficiency score (inverse measure of output orientation);
- λ_j are intensity variables;
- x_{kj} and y_j denote inputs and outputs.

Efficiency scores are normalized to lie between 0 and 1, with unity indicating full efficiency.

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