Space and Infrastructural Optimization: To What Extent Do Resource-Based Determinants Affect Educational Outcomes in Indian States from 2017 to 2020?

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Abstract

The education and infrastructure landscape in India has evolved significantly, reflecting the country's broader socio-economic development. Post-independence, India struggled to build an inclusive education system due to infrastructural limitations like inadequate school buildings, lack of functional toilets, clean water shortages, and insufficient resources, particularly in rural areas. Even by the 1990s, these challenges persisted, but economic liberalization spurred government initiatives aimed at improving access and quality, with the Right to Education Act (RTE) of 2009 marking a critical turning point. Over the last decade, the focus has increasingly shifted toward standardizing educational quality, with the National Education Policy (NEP) 2020 emphasizing regional disparities, infrastructural development, and holistic, inclusive education. While prior studies have explored this area, a more rigorous methodological approach of panel-data technique has been employed instead of the standard cross-sectional approach. This study analyses the impact of 14 explanatory variables on 4 proxies of educational outcomes: enrolment, retention, learning outcomes and quality, and equity in the 35 States and Union Territories from 2017 to 2020. Additionally, State and Union Territory level differences have been considered. The study employs a Random Effects Model for each of the four analyses, factoring in a total of 4260 observation points. The findings reveal that governance processes regarding transparency and accountability improve retention and equity in the educational system, while technology negative impacts enrolment and learning outcomes. The study highlights that the role of playgrounds and physical facilities like hand-rails and ramps is to be carefully assessed with them having positive and negative impacts on different dependent variables. It's essential to improve the supplementary reading materials, supply of functional electricity, and furniture in the classrooms to improve the learning outcomes while rainwater harvesting has a significant positive impact on enrolment. The evolving and multifaceted nature of education systems underscores the need for this study - a more holistic approach to studying education, considering a variety of factors. The research provides valuable insights for policymakers to address all aspects of education in India.

Keywords: Retention, Governance processes, Equity, Enrolment, Regional disparity

DATA

Sampling and Data Collection

This research is a quantitative study using secondary data from the Unified District Information System for Education (UDISE) - which presents school, State, Union Territories, and nation wise information about the education system in India – and the Performing Grading Index released by the Department of School Education and Literacy, Ministry of Education, Government of India.

The study employs a panel-data analysis which allows for tracking changes in educational factors over four years. This allows for a certain continuity that enables the analysis to provide a higher-level efficiency with more variability in terms of variables used. It provides a more nuanced understanding by considering how regional factors and disparities evolve over time. The use of panel data also contributes

further to the literature since the majority of studies in this field tend to focus on short-term or static comparisons.

The study is conducted using annual data for four years from 2017 to 2020. The study is a panel data analysis which includes 35 States and Union Territories in total. The states and Union Territories included are shown in Table 1.

Table 1: Sample Units (N=35)

Andaman & Nicobar Islands	Goa	Madhya Pradesh	Rajasthan
Andhra Pradesh	Gujarat	Maharashtra	Sikkim
Arunachal Pradesh	Haryana	Manipur	Tamil Nadu
Assam	Himachal Pradesh	Meghalaya	Telangana
Bihar	Jammu and Kashmir	Mizoram	Tripura
Chandigarh	Jharkhand	Nagaland	Uttarakhand
Chhatisgarh	Karnataka	Odisha	Uttar Pradesh
Daman and Diu, Dadra and Nagar Haveli	Kerala	Puducherry	West Bengal
Delhi	Lakshadweep	Punjab	

Of all Indian States and Union Territories, Ladakh has been excluded due to the unavailability of data prior to 2019. Additionally, Daman and Diu and Dadra and Nagar Haveli have been combined as one for 2017 and 2018 by taking an average of all values due to the presentation of that format of data for the years 2019 and 2020.

The necessary data has been collected for a period of 4 years from 2017 to 2020, resulting in a total number of 4260 observations.

Data Cleaning

During data collection, any missing data points were addressed using the Simple Moving Averages (SMA) technique, which calculates the average of available data points in a defined window around the missing values. This method helped ensure smooth fluctuations and provided realistic estimates based on existing trends.

In the process of data arrangement, an important part was the creation of a panel to facilitate the longitudinal analysis of variables across the four years. The initial data was repositioned State/Union Territory wise using the order and sort command. After the generation of a unique ID for each State or Union Territory, the data was converted from a wide to a long format, specifying State as the panel identifier and Year as the time variable.

Descriptive Statistics

Table 2: Descriptive Statistics for Independent Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
LandAvailable	140	29638.821	35939.322	26	171610
FunctionalElectric~y	140	32876.736	38607.198	45	200059
Playground	140	32269.446	40613.452	29	202465
ReadMat	140	19386.219	22583.939	26.333	97399.336
Furniture	140	27776.079	30420.755	45	182092
FunctionalToiletan~l	140	21258.761	33074.801	0	171966
GirlTU	140	30231.204	38718.987	22.5	206086
BoyTU	140	29572.493	37998.823	22.5	204511
RainWaterHarvesting	140	7456.282	11444.903	0	54055
PureWater	140	9301.102	12464.822	0	54620
AddPhyFac	140	23896.662	31297.494	14	162272
Med	140	23602.591	28304.861	13.5	152059.5
Tech	140	24520.264	29348.093	59	124208
GP	140	241.875	58.093	129	348

The first independent variable, land availability, averages 39,639 schools meeting the required criteria, but numbers vary widely, ranging from 27.75 in State 18 to 168,832.5 in State 34. This stark disparity points to regional differences in infrastructure development. Functional electricity follows a similar pattern, with an average of 32,876 schools. While states like State 34, 19, and 20 show high numbers of schools with electricity, others, such as State 18 and State 6, have very limited access. Playgrounds are available in 39.5 schools in State 18 compared to 196,546 in State 34, reflecting differences in investment in recreational educational facilities, which may impact student well-being. The average number of schools with reading materials is 193,686, but it is surprising that access remains inconsistent.

Furniture availability shows large disparities, a basic necessity that is still unmet in many schools. Functional toilets and urinals for girls have a slightly higher mean than for boys, showing a focus on gender-specific needs, but large regional differences remain in access. Rainwater harvesting systems are present in an average of 7,457 schools, while pure water is accessible in 9,301 schools. However, some states provide no access to pure water – denoted by a minimum of zero – posing significant risks to student health. Additional physical facilities for students with disabilities, such as ramps and handrails, average 23,896 schools but show wide discrepancies, indicating a lack of emphasis on inclusivity.

The availability of medical facilities, measured through medical and complete medical checkups, averaging 23,603 schools, remains insufficient in many states, with only 14 schools in some cases. Technology resources, averaging 24,520 schools, show considerable variation, with high standard deviations pointing to unequal access across regions. The governance processes variable, with a mean of 241.88, reflects differences in policy implementation and oversight, crucial for managing educational outcomes.

Overall, these variables underscore significant disparities in educational infrastructure across states, highlighting the need for targeted interventions.

Table 3: Descriptive Statistics for Dependent Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
EnTWPTotal	140	16.472	20.962	.026	100
Ret	140	76.858	17.325	34.89	100
LOQ	140	76.317	7.497	55.556	93.333
EQ	140	90.537	4.573	73.478	99.13

The trend of high variation continues extensively with the dependent variables as well. While the enrolment rate has a mean of only 16.472, which represents that the mean is in the first quadrant of enrolment rate. This signifies that the majority of States have low rates for enrolment, a cause of concern. The extremely low minimum of 0.026, however, can be explained due to the restricted geographic locations and small size, since it belongs to Lakshadweep. On the other hand, the mean for retention lies in the fourth quadrant with an average of 76.858. This indicates that while the mean retention is high, there is still room for improvement, especially with a minimum of 34.89. Learning outcomes and quality also lies in the last quadrant with an average of 76.317. However, the differences in minimum and maximum reflect inconsistencies in educational delivery. It's particularly interesting to note that the status of equity is better than any of the other dependent variables, with a mean of 90.537.

METHODOLOGY

Research Aim

The purpose of this study is to identify the impact of fourteen factors, measures of facilities, infrastructure, and services offered, on the educational outcomes of students in 35 states and union territories of India from 2017 to 2020. The fourteen explanatory variables considered are land availability, provision of functional electricity, availability of playground, access to additional reading materials, adequate furniture, functional toilet and urinal facilities, girls' toilets and urinals, boys' toilets and urinals, rain water harvesting systems, availability of pure water, medical checkups, access to technology, and government processes. These variables' impact on educational outcomes has been considered in a multitude of different ways. Educational outcomes have been measured in four fundamental ways: 1) Enrolment 2) Retention 3) Learning outcomes and quality and 4) Equity of the system.

Model Specification and Research Design

To examine the influence of the 14 factors on the educational outcomes and standards in the 35 States and Union Territories in India from 2017 to 2020, panel data regression analysis was conducted. Educational outcomes and standards have been examined in terms of four measures: 1) Enrolment of students 2) Retention 3) Learning outcomes and quality and 4) Equity of the system. For understanding the extent of the impact of the factors on these dependent variables, four models have been crafted. The given table represents the five models and dependent variable in each model:

Table 4: Model Description

	Dependent Variable
Model 1	EnTWPTotal, Total Enrolment Rate
Model 2	Ret, Retention
Model 3	LOQ, Learning Outcomes and Quality
Model 4	EQ, Equity

In order to identify the regression model – Fixed Effects Regression or Random Effects Regression – most suited for each model, the Hausman specification test has been utilised for the differentiation. However, the test stated that the difference in coefficients was not systematic. As a result, the Random Effects Regression Model has been utilised for all models since it fit the available data better.

The generalised Random Effects Regression Model used for each of the four models is given as follows:

$$y_{it} = \alpha_i + \beta_1 x^1{}_{it} + \beta_2 x^2{}_{it} + \beta_3 x^3{}_{it} + \beta_4 x^4{}_{it} + \beta_5 x^5{}_{it} + \beta_6 x^6{}_{it} + \beta_7 x^7{}_{it} + \beta_8 x^8{}_{it} + \beta_9 x^9{}_{it} + \beta_{10} x^{10}{}_{it} + \beta_{11} x^{11}{}_{it} + \beta_{12} x^{12}{}_{it} + \beta_{13} x^{13}{}_{it} + \beta_{14} x^{14}{}_{it} + \gamma_1 q^1{}_{it} + \gamma_2 q^2{}_{it} + \gamma_3 q^3{}_{it} + \cdots + \gamma_{33} q^{33}{}_{it} + \gamma_{34} q^{34}{}_{it} + \gamma_{35} q^{35}{}_{it} + \epsilon_{it}$$

Here, y_{it} is the dependent variable, α_i is the unobserved effect, β_j is the estimated coefficient of the explanatory variables, x_j represents the fourteen independent variables, γ_j is the estimated coefficient of the 35 categorical variables, q_j represents the 35 categorical variables considered, and e_{it} is the estimated error value in the equation.

Diagnostic Tests

As previously mentioned, for all models a Random Effects Regression is going to be conducted. However, before presenting these results of the regression equations, the assumptions to carry out such a technique must be met. All models should have an absence of autocorrelation and heteroskedasticity. In the case these conditions are not met, certain adjustments to take these factors into consideration will be made.

Autocorrelation

The presence of autocorrelation in a data set implies that the values pertaining to a time series are influenced over successive time intervals or by a lagged version of itself. This indicates that the data is not purely random, which further leads to inaccurate results especially regarding the significance levels and coefficients.

The Wooldridge Test for autocorrelation in a panel data set has been utilised for all four? models. The null hypothesis for the test states the following:

H_0 = There is no first-order autocorrelation

Hence, a P-Value of less than 0.05 indicates the rejection of the null hypothesis and indicates the presence of autocorrelation while a P-Value greater than 0.05 indicates the acceptance of the null hypothesis and absence of autocorrelation.

The p-values for all models are given below:

Table 5: Wooldridge Test for autocorrelation in panel data

	P-Value
Model 1	0.0152
Model 2	0.0080
Model 3	0.0031
Model 4	0.0584

Hence, it is observed that Models 1, 2, and 3 reject the null hypothesis and have autocorrelation.

Heteroskedasticity

The presence of heteroskedasticity indicates that the variance of error terms or residuals is not constant across all levels of the explanatory variables. Hence, the dispersion of residuals is different for different values which can result in biased and inconsistent estimates of standard errors, leading the significance levels and accuracy. Hence, the presence of homoskedasticity is crucial for a regression analysis.

White's test for heteroskedasticity has been utilised which has the following null hypothesis:

$$H_0 = \text{Presence of homoskedasticity}$$

Hence, a P-Value of less than 0.05 indicates the rejection of the null hypothesis and presence of heteroskedasticity while a P-Value greater than 0.05 indicates the acceptance of the null hypothesis and presence of homoskedasticity.

The P-Value and Chi-Square Statistic for all five models is given below:

Table 6: White test for heteroskedasticity

	Chi-Square Statistic	**P-Value**
Model 1	160.29	0.0418
Model 2	138.83	0.3032
Model 3	110.64	0.9012
Model 4	140.92	0.2615

Hence, it is observed that only Model 1 rejects the null hypothesis and has heteroskedasticity.

Variables and Hypotheses

Table 7 describes the 14 dependent (DV) and 4 independent variables (IV) that have been used in the study.

Table 7: Description of Variables

	Symbol	Variable Name	Definition	Measured by (Source, Variable Name or Formula)	Rationale
DV	LandAvailable	Land Available	Total number of schools that provide adequate land to their students.	UDISE, Land Available variable	By allowing schools to expand their other facilities, build more classrooms, playgrounds, or other specialised spaces, and also increasing a school's ability to enrol more students, land availability plays a critical role while affecting the educational outcome.
DV	FunctionalElectricity	Functional Electricity	Total number of schools with functional electricity in the given State.	UDISE, Functional Electricity variable	Consistent access to electricity affects attention and retention, as students are more likely to attend schools with basic comfort. Further, digital access and more advanced interactive and technologically abled teaching methods can be used.
DV	Playground	Playground	Total number of schools with a playground in the given State.	UDISE, Playground variable	Playgrounds provide a space for physical activity and enjoyment, often correlated with cognitive function, social interaction, and mental health. By fostering a holistic development of students, the playground enables a well-rounded school experience, improving educational participation and outcomes.
DV	ReadMat	Reading Materials Available	At least one of the three	UDISE, (Library or Reading Corner or Book Bank + Librarian + Newspaper)/3	The availability of numerous reading materials or supplementary resources improves general literacy and furthers academic growth, beyond the bounds of the traditional classroom.
DV	Furniture	Furniture	Total number of schools with furniture in the given State.	UDISE, Furniture variable	Adequate and comfortable furniture, including desks, chairs, boards, etc. are conducive for a learning environment.

	Symbol	Variable Name	Definition	Measured by (Source, Variable Name or Formula)	Rationale
DV	FunctionalToiletandUrinal	Functional Toilet and Urinal	Total number of schools with sufficient toilet and urinal facilities provided to students.	UDISE, Functional Toilet and Urinal variable	Proper facilities concerning toilets and urinals are essential and help reduce doubt for enrolling students in schools or absenteeism. Especially with reference to rural parts of India, where sanitation issues yet prevail, access to such facilities may directly influence enrolment rates.
DV	GirlTU	Female Toilet and Urinal	Total number of schools with a functional toilet or urinal for girls in the given State.	UDISE, (Girl's Toilet + Functional Urinal Girl's)/2	The availability of functional toilets for girls is critical for their education and gender equity. Lack of privacy or cleanliness may result in a lesser productive or negative learning environment.
DV	BoyTU	Male Toilets and Urinal	Total number of schools with a functional toilet or urinal for boys in the given State.	UDISE, (Boy's Toilet + Functional Urinal Boy's)/2	Clean and functional toilets help promote a more balanced and healthy learning environment, while encouraging attendance and retention due to focus.
DV	RainWatHarvesting	Rain Water Harvesting Facilities	Total number of schools with rainwater harvesting facilities in the given State.	UDISE, Rainwater Harvesting variable	Schools with rainwater harvesting systems ensure a consistent water supply for drinking and other sanitation purposes. Additionally, in rural areas in India, rainwater harvesting is considered an essential environmental responsibility, which could make parents more included to send their children.
DV	PureWater	Clean Water Provision	Total number of schools with water purifiers or functional drinking water facility in the given State.	UDISE, (Water Purifier + Water Tested)/2	Access to clean drinking water is important for maintaining student health and concentration. It can result in lesser absenteeism and higher academic performance.
DV	AddPhyFac	Additional Physical Facilities	Total number of schools with hand rails or ramps in the given State	UDISE, (Hand-Rails + Ramps)/2	Assessing the importance of physical accessibility and inclusivity in schools, especially for students with

	Symbol	Variable Name	Definition	Measured by (Source, Variable Name or Formula)	Rationale
					disabilities or mobility challenges, is essential since it can foster an equitable learning environment, improving outcomes.
DV	Med	Medical Checkups	Total number of schools that conduct medical checkups or complete medical checkups in the given State.	UDISE, (Medical Checkup + Complete Medical Checkup)/2	Medical checkups in school help in early detection of health issues, thereby severely impacting learning outcomes. Additionally, specifically in low-income areas where access to healthcare is limited, such facilities may incentivize attendance and enrolment.
DV	Tech	Technology	Total number of schools that provide sufficient internet and computer facilities to students.	UDISE, Internet + Computer Available	Access to internet allows students and teachers to use online resources, engage in digital platforms, thereby improving the quality of education. Connectivity also helps bridge the digital divide and improves equity in education.
DV	GP	Government Processes	Systematic administration and monitoring to ensure transparency and accountability of government actions in the education sector, by reducing human interference and promoting technology.	Performance Grading Index, Government Processes	Government process, with regards to efficiency and accountability especially, result in more optimal allocation of funds, infrastructure, and staff. This helps improve teacher performance and student attention, while reducing any delays. It ensures a fair and efficient education system, improving overall outcomes.
DV	State	State and Union Territory Variable	Accounts for the individual State and Union Territory level differences with State 9, Delhi being used as the benchmark. Delhi was chosen due its status as the capital of India.	ib9.State	The varying region-wise factors in terms of governance, socio-economic factors, and policy implementation, significantly affect the educational status.

	Symbol	Variable Name	Definition	Measured by (Source, Variable Name or Formula)	Rationale
IV	EnTWPTot	Total Enrolment, including preschool	Total number of students enrolled from preschool to Grade 10.	UDISE, (Enrolment by Location, Including Primary)/(Max Enrolment Rate of the Year) x 100	Provides a clear indicator of participation and invovlvemnt of students in education. Effectively portrays the reach of the education system and inclusivity, which is important as a measure of educational success.
IV	LOQ	Learning Outcomes and Quality	Measures achievement outcomes of students using language and mathematics scores from Grades 3, 5, and 8.	Performance Grading Index, (Government Processes/180) x 100	Provides a direct assessment of the academic achievement of students in foundational subjects like language and mathematics, thereby indicating cognitive development.
IV	Ret	Retention	Indicates the retention rate of students.	UDISE, (Overall primary retention rate + Overall elementary retention rate + Overall secondary retention rate)/3	Indicates the presence of a supportive and engaging learning environment that encourages continued participation. Helps understand the progression of students through levels, without dropping out, thereby indicating active participation.
IV	EQ	Equity	Indicates whether all students, regardless of their socio-economic background, caste, gender, geographic location, or disabilities, have equal access to education and related opportunities.	Performance Grading Index, (Equity/230) x 100	Is essential for understanding whether the educational system addresses and reduces inequalities in the fair access to education for all.

Following are the hypotheses for Model 1:

1. H_{1M1}: There is an insignificant positive impact of land availability on the total enrolment rate.
2. H_{2M1}: There is a significant positive impact of functional electricity on the total enrolment rate.
3. H_{3M1}: There is a significant positive impact of playgrounds on the total enrolment rate.
4. H_{4M1}: There is a significant positive impact of additional reading materials on the total enrolment rate.
5. H_{5M1}: There is a significant positive impact of furniture on the total enrolment rate.

6. H_{6M1}: There is a significant positive impact of functional toilet and urinal facilities on the total enrolment rate.
7. H_{7M1}: There is a significant positive impact of toilets and urinals for females on the total enrolment rate.
8. H_{8M1}: There is an insignificant positive impact of toilets and urinals for males on the total enrolment rate.
9. H_{9M1}: There is an insignificant positive impact of rainwater harvesting systems on the total enrolment rate.
10. H_{10M1}: There is a significant positive impact of clean water provision on the total enrolment rate.
11. H_{11M1}: There is a significant positive impact of additional physical facilities on the total enrolment rate.
12. H_{12M1}: There is a significant positive impact of provision of medical checkups on the total enrolment rate.
13. H_{13M1}: There is a significant positive impact of additional technological resources on the total enrolment rate.
14. H_{14M1}: There is a significant positive impact of implementation of government processes on the total enrolment rate.

Following are the hypotheses for Model 2:

1. H_{1M2}: There is an insignificant positive impact of land availability on the total retention rate.
2. H_{2M2}: There is a significant positive impact of functional electricity on the total retention rate.
3. H_{3M2}: There is an insignificant positive impact of playgrounds on the total retention rate.
4. H_{4M2}: There is an insignificant positive impact of additional reading materials on the total retention rate.
5. H_{5M2}: There is an insignificant positive impact of furniture on the total retention rate.
6. H_{6M2}: There is a significant positive impact of functional toilet and urinal facilities on the total retention rate.
7. H_{7M2}: There is a significant positive impact of toilets and urinals for females on the total retention rate.
8. H_{8M2}: There is an insignificant positive impact of toilets and urinals for males on the total retention rate.
9. H_{9M2}: There is an insignificant positive impact of rainwater harvesting systems on the total retention rate.
10. H_{10M2}: There is a significant positive impact of clean water provision on the total retention rate.
11. H_{11M2}: There is a significant positive impact of additional physical facilities on the total retention rate.
12. H_{12M2}: There is an insignificant positive impact of provision of medical checkups on the total retention rate.
13. H_{13M2}: There is an insignificant positive impact of additional technological resources on the total retention rate.
14. H_{14M2}: There is an insignificant positive impact of implementation of government processes on the total retention rate.

Following are the hypotheses for Model 3:

1. H_{1M3}: There is an insignificant positive impact of land availability on the learning outcomes and quality of education.
2. H_{2M3}: There is a significant positive impact of functional electricity on the learning outcomes and quality of education.
3. H_{3M3}: There is a significant positive impact of playgrounds on the learning outcomes and quality of education.
4. H_{4M3}: There is a significant positive impact of additional reading materials on the learning outcomes and quality of education.
5. H_{5M3}: There is an insignificant positive or negative impact of furniture on the learning outcomes and quality of education.
6. H_{6M3}: There is an insignificant positive or negative impact of functional toilet and urinal facilities on the learning outcomes and quality of education.
7. H_{7M3}: There is an insignificant positive impact of toilets and urinals for females on the learning outcomes and quality of education.
8. H_{8M3}: There is an insignificant positive or negative impact of toilets and urinals for males on the learning outcomes and quality of education.
9. H_{9M3}: There is an insignificant positive or negative impact of rainwater harvesting systems on the learning outcomes and quality of education.
10. H_{10M3}: There is an insignificant positive impact of clean water provision on the learning outcomes and quality of education.
11. H_{11M3}: There is an insignificant positive impact of additional physical facilities on the learning outcomes and quality of education.
12. H_{12M3}: There is a significant positive impact of provision of medical checkups on the learning outcomes and quality of education.
13. H_{13M3}: There is a significant positive impact of additional technological resources on the learning outcomes and quality of education.
14. H_{14M3}: There is a significant positive impact of implementation of government processes on the learning outcomes and quality of education.

Following are the hypotheses for Model 4:

1. H_{1M4}: There is an insignificant positive or negative impact of land availability on equity.
2. H_{2M4}: There is an insignificant positive impact of functional electricity on equity.
3. H_{3M4}: There is a significant positive impact of playgrounds on equity.
4. H_{4M4}: There is a significant positive impact of additional reading materials on equity.
5. H_{5M4}: There is a significant positive impact of furniture on equity.
6. H_{6M4}: There is a significant positive impact of functional toilet and urinal facilities on equity.
7. H_{7M4}: There is a significant positive impact of toilets and urinals for females on equity.
8. H_{8M4}: There is an insignificant positive impact of toilets and urinals for males on equity.
9. H_{9M4}: There is an insignificant positive impact of rainwater harvesting systems on equity.
10. H_{10M4}: There is a significant positive impact of clean water provision on equity.
11. H_{11M4}: There is a significant positive impact of additional physical facilities on equity.
12. H_{12M4}: There is a significant positive impact of provision of medical checkups on equity.
13. H_{13M4}: There is a significant positive impact of additional technological resources on equity.
14. H_{14M4}: There is a significant positive impact of implementation of government processes on equity.

RESULTS AND DISCUSSION

The diagnostic tests indicate that Models 1, 2 and 3 are plagued with autocorrelation while only Model 1 has heteroskedasticity. To overcome the biassed and inaccurate standard errors that are caused, clustering has been used in Models 1, 2, and 3 to obtain robust standard errors. The 'vce(cluster id)' function in STATA has been utilised to overcome these challenges, ensuring that the assumptions required for the Random Effects Regression Model are being met.

Model 1: Enrolment rate

Table 8: Results of Panel Data Regression Using Random Effects Model for Model 1

DV: EnTWPTotal	Coefficient	P-Value
LandAvailable	6.44e-06	0.905
FunctionalElectricity	-1.19e-06	0.929
Playground	.0000536	0.008***
ReadMat	.0000157	0.684
Furniture	9.02e-06	0.325
FunctionalToiletandUrinal	.0000308	0.107
GirlTU	-.0000237	0.743
BoyTU	-.0000537	0.406
RainWaterHarvesting	.0000561	0.097*
PureWater	.0000126	0.438
AddPhyFac	-.0000281	0.067*
Med	.0000103	0.295
Tech	-.0000288	0.086*
GP	-.0008968	0.410
Constant	9.884588	0.000

R-squared	0.9997	Number of obs	140

****p<0.01, **p<0.05, *p<0.1*

As seen in Table 8, it is observed that the R^2 value is 0.9997 which indicates that 99.97 percent variation in the dependent variable is explained by the 14 variables considered and the categorical variable of State-level differences.

It's crucial to note that using State 9 as the base category, all other 35 state-level indicators were significant. In fact, all of them were significant at 1 percent significance, indicating that they had majorly affected the total enrolment rate. The coefficients for these state-level categorical variables reflect the variations in enrolment across States, and the unique regional factors that affect them.

Of the 14 explanatory variables considered, four were significant – Playground, RainWaterHarvesting, AddPhyFac, and Tech. With reference to the beta values or coefficients of the equation, we can conclude that AddPhyFac and Tech had a negative influence on EnTWPTotal at 10 percent significance for both, while Playground and RainWaterHarvesting had a positive influence at 1 and 10 percent significance respectively. Ultimately, this means that an increase in schools with playgrounds and rainwater harvesting systems will result in an increase in enrolment rate while an increase in schools with additional physical facilities – such as ramps and hand-rails – and technological components – such as computers and internet

access – will result in a decrease in enrolment. Overall, this leads to the rejection of the rejection of 4 null hypotheses: H_{3M1}, H_{9M1}, H_{11M1}, and H_{13M1}.

The significant positive impact of playgrounds can be explained since playgrounds provide a place for physical activity and overall development. Schools that provide these benefits may be considered as better for the holistic development of students than those that don't provide these facilities. Hence, enrolment in these schools may be higher, due to the students' better overall well-being. This finding is supported by Davison & Lawson (2006), who emphasize that attributes in the physical environment, such as playgrounds, promote physical activity, which, in turn, encourages better school participation. Similarly, Dyment et al. (2009) found that school ground design has a positive impact on students' activity levels and engagement. However, some studies, such as Brown et al. (2020) highlight that poorly maintained or inaccessible playgrounds, especially for students with disabilities, may not always contribute to increased enrolment.

Rainwater harvesting systems also have a significant positive impact on enrolment rates. This can be explained due to the critical role of water in maintaining hygiene and hence, a conducive learning environment. Furthermore, numerous parts of rural India face water scarcity, making such schools with a reliable supply of water more attractive, since water may otherwise be a limited resource. Studies like Silva Vieira et al. (2013) and Parung School Case Study (2021) show that rainwater systems reduce the dependency on external water supplies and improve attendance rates in schools. However, Viera et al. (2013) also indicates that poorly maintained or unfiltered rainwater systems could pose health risks, potentially deterring parents from enrolling their children.

Thirdly, additional physical facilities have a negative impact on enrolment rate. This can be justified by the fact that these facilities are more often implemented in schools serving a specific student population, particularly those with physical disabilities. As a result, the overall enrolment rate would be lower due to which they appear to have a negative impact. A study by Dyment et al. (2009) demonstrated that ramps and inclusive features are critical for creating a welcoming environment for all students, particularly those with mobility impairments. However, (Brown et al., 2020) also shows that in many cases, these facilities are underutilized or seen as secondary to other needs, resulting in limited overall enrolment growth.

It's surprising to notice that technology has a significant negative impact on enrolment rates. However, it can be explained due to the difference in quality and advancement of technology, specifically availability of computer and access to internet, between urban and rural areas in India. Furthermore, the mere of presence of technology may not be sufficient to attract students – presence of capable teachers and its integration in the curriculum is necessary to make an impact. Also, the socio-economic challenges in affording schools with such technology may be a barrier to the full realization of the benefits, resulting in a lower enrolment rate in schools focused on tech-based learning. Studies such as BuildHealth (2022) and Dyment et al. (2009) note that in some regions, particularly where there is a significant digital divide, technology has not been fully integrated into the curriculum, which limits its potential to increase enrolment. Furthermore, they state that competition from private schools offering advanced digital education options can reduce public school enrolment in urban settings.

State and Union Territory-level differences, accounted for by the categorical variable, significantly impact the enrolment rates due to the different social, economic, and political factors that vary across these regions. Difference in educational policies, funding for resources, efficacy of governance, cultural attitudes – specifically towards marginalised groups, and regulation of schemes, may affect the enrolment rates. In particular, Andaman and Nicobar Islands, Arunachal Pradesh, Chhattisgarh, Goa, Himachal Pradesh, and 11 other states have an enrolment rate lower than that of the base state, Delhi. However, the

remaining 18 states have social, political, and economic status that favours the enrolment rate which is equal or closer to that of the base state, Delhi.

Model 2: Retention

Table 9: Results of Panel Data Regression Using Random Effects Model for Model 2

DV: Ret	Coefficient	P-Value
LandAvailable	-.000013	0.982
FunctionalElectricity	.0001079	0.233
Playground	.0000666	0.754
ReadMat	.0006673	0.172
Furniture	.0000381	0.648
FunctionalToiletandUrinal	.0002397	0.623
GirlTU	-.0003344	0.618
BoyTU	-.0002604	0.679
RainWaterHarvesting	.0003428	0.570
PureWater	.0000165	0.947
AddPhyFac	.0002471	0.407
Med	-.0000302	0.746
Tech	-.0000473	0.790
GP	.0331305	0.055*
Constant	80.80811	0.000

R-squared	0.9415	Number of obs	140

****p<0.01, **p<0.05, *p<0.1*

As seen in Table 9, we notice that the R^2 value is 0.9415. This signifies that the 94.15 percent variation in the retention rate is explained by the 14 variables considered and the individual State and Union Territory level differences.

Of the 34 State level difference indicators, thirteen were significant at 1 percent, five were significant at 5 percent and seven were significant at 10 percent. This implies that the individual state level differences played an immense role in affecting the retention rate amongst students.

Of the other 14 independent variables considered, however, only one was significant. Governance processes was significant at 1 percent significance with a positive coefficient of 0.033. Hence, this results in the rejection of the null hypothesis H_{14M2}. The positive significant impact of government processes can easily be explained. Firstly, the monitoring of teacher attendance and transparent systems for recruitment, promoted by the independent variable, helps ensure that schools are constantly well-staffed with committed teachers. It created a stable learning environment, thereby improving the retention rate by increasing the number of students continuing in the education system. Secondly, School Leadership training sessions fostered by the variable positive influences the retention further. Thirdly, efficient allocation of funds enables schools to maintain operational continuity and the provision of resources which help retain students further. Lastly, the regular monitoring of schools and inspections ensure that standards are maintained, which makes schools more conducive for long-term student engagement.

This positive impact of Governance processes is also highlighted by Khan & Iqbal (2014) who demonstrated that improved governance in school systems, including better leadership and administrative processes, positively impacts both student enrolment and retention. They found that when government processes such as teacher training, transparent recruitment, and fund disbursement are efficient, it directly correlates to better school environments and higher retention rates. Another study by Muralidharan & Sundararaman (2011) supports this finding by highlighting how regular teacher evaluations and the use of performance incentives improve teacher retention, which indirectly affects student retention through improved learning environments. However, Dyer (2015) argues that in regions with poor implementation of government processes, such as delayed fund disbursement or inefficient teacher transfers, the impact on retention is minimal or even negative. This occurs when government inefficiencies lead to resource shortages or staff dissatisfaction, which in turn affects the learning environment and causes students to drop out. Similarly, Kingdon & Teal (2010) found that while government processes theoretically improve retention, in practice, if not effectively monitored, they may fail to deliver significant outcomes, particularly in regions where there is a high level of bureaucratic delay and weak enforcement of policies.

It is surprising to note technology's insignificance in this case. Technology, often considered a major factor with regards to education, enhances learning opportunities, digital literacy, and engagement. It is expected that access to computers and internet services could result in higher retention due to modern advancement.

The categorical variable of State and Union Territory-level differences have also proved to be highly significant. Infrastructural development and investment into facilities, that are different according to State policies and decision, have an important impact on the retention rate. Furthermore, supportive government policies that emphasise consistent attendance by teachers and students also improve retention, contrary to other States that don't. Moreover, geographically isolated States or generally lesser developed States struggle with retention due to the limited access to schools and poor infrastructure. Hence, it's important to consider these differences.

Model 3: Learning outcomes and quality

Table 10: Results of Panel Data Regression Using Random Effects Model for Model 3

DV: LOQ	Coefficient	P-Value
LandAvailable	-.0001628	0.251
FunctionalElectricity	.0001341	0.012**
Playground	.0000196	0.897
ReadMat	.0003101	0.017**
Furniture	.0001341	0.000***
FunctionalToiletandUrinal	-.0000468	0.458
GirlTU	-.0000403	0.834
BoyTU	.0001236	0.633
RainWaterHarvesting	-.0001047	0.527
PureWater	.0000651	0.555
AddPhyFac	-.0000273	0.609
Med	.000028	0.165
Tech	-.0000396	0.081*
GP	-.0009996	0.880
Constant	67.17196	0.000

R-squared	0.9707	Number of obs	140

****p<0.01, **p<0.05, *p<0.1*

As seen in Table 10, it is noticed that the R^2 value is 0.9707 which indicates that 97.07 percent of the dependent variable – Learning Outcomes and Quality – is explained by the 14 independent and 34 categorical State and Union Territory variables considered.

It's essential to note that thirteen of the categorical variables were significant at 1 percent, three were significant at 5 percent, and three were significant at 3 percent. This implies that the individual State level differences play a major role in the learning outcomes and quality provided by the education system.

Of the 14 explanatory variables considered, four were significant – FunctionalElectricity, ReadMat, Furniture, and Tech. With reference to the beta values or coefficients of the equation, we can conclude that FunctionalElectricity, ReadMat, and Furniture had a positive impact on LOQ at 5 percent, 5 percent, and 1 percent respectively while Tech negatively impacted LOQ at 10 percent significance. Thus, the findings indicate that an increase in schools with functional electricity, supplementary reading materials and related facilities – libraries or book-reading corners, librarians, and newspapers – and furniture will help improve the quality of the education. On the other hand, however, an increase in schools with internet and computer facilities will worsen the education quality. Overall, this leads to the rejection of the rejection of 4 null hypotheses: H_{2M3}, H_{4M3}, H_{5M3}, and H_{13M3}.

Functional electricity's positive influence on learning outcomes and quality can be justified since functional electricity directly affects the classroom environment and the physical well-being of students and teachers. The comfortable learning environment it ensures helps maintain student focus and attention, thereby improving the education quality. Studies by Mendell & Heath (2005) indicate that classrooms with proper lighting lead to better student performance by reducing eye strain and improving concentration. Similarly, research by Schneider (2002) found that schools with proper lighting and ventilation, both of which are reliant on functional electricity, show higher student achievement and fewer health-related absences. Further, Crum & Cerra (2009) found that maintaining a comfortable temperature through electricity-powered heating and cooling systems enhances students' ability to concentrate and reduces fatigue, leading to better academic performance. However, other studies, such as one by McGuffey (1982), argue that while electricity is important, the correlation between electricity and academic performance diminishes when other factors, such as socio-economic status or teacher quality, are introduced. This suggests that electricity alone may not be a primary driver of learning outcomes but acts in conjunction with other elements.

Another variable that had a positive, significant impact on LOQ, was reading materials. Access to such materials through libraries, book-reading corners, and newspapers help students foster interest for reading and independent learning, sometimes beyond the bounds of their academic needs. Access to resources can help further develop their skills. Research by Krashen (2004) emphasizes the role of reading in developing literacy skills, critical thinking, and comprehension, which are essential for academic success. Libraries and reading corners promote independent learning, allowing students to explore topics beyond the curriculum, fostering deeper understanding. Additionally, Elley (1992) found that schools with well-stocked libraries have higher literacy rates, particularly in under-resourced communities where students might not have access to books outside of school. However, studies like Williams & Wavell (2001) argue that simply providing access to reading materials does not automatically result in better learning outcomes unless students are encouraged and guided to make use of them effectively. In many cases, without proper

support from teachers or librarians, the availability of reading materials may be underutilized, thus limiting their impact.

Furniture was also found to play a significant role in enhancing learning outcomes. Adequate furniture such as desks and chairs help improve concentration and reduce physical strain, thereby allowing students to focus for longer periods without any distractions. An important aspect to note is the arrangement of furniture which can promote a collaborative learning environment and interactive activities. Research by Higgins et al. (2005) shows that well-designed, ergonomic furniture reduces physical discomfort, which in turn allows students to concentrate for longer periods. Proper seating arrangements also encourage active learning, as flexible furniture setups can support group work and collaborative learning, leading to improved problem-solving skills. Furthermore, Barrett et al. (2015) found that the physical design of learning spaces, including furniture, has a measurable impact on student engagement and academic performance, as students who are comfortable are more likely to participate actively in lessons. On the other hand, Earthman (2004) argues that while furniture quality is important, other environmental factors like teacher effectiveness and school resources have a more significant influence on learning outcomes. The study suggests that while good furniture supports learning, it is not as impactful without strong pedagogical practices.

It is interesting to note that technology has a significant, negative impact on learning outcomes and quality. In addition to these technological resources possibly posing a distraction for students if used for non-learning purposes, they also have the possibility of students becoming overly reliant on these tools, thereby degrading the quality of learning outcomes. Furthermore, it's important to note that the differences in access to such resources may result in widening the gap between learning outcomes, causing disparities in academic achievement. Research by Ravizza et al. (2017) demonstrated that students who multitask using laptops during lessons tend to perform worse on exams due to divided attention. The constant availability of the internet can lead to distractions, such as social media or gaming, detracting from focus on academic content. Moreover, Selwyn (2016) found that in environments with unequal access to technology, the digital divide can exacerbate inequalities in education, as not all students have the same level of access to computers and the internet outside of school, leading to uneven learning outcomes. However, Means et al. (2010) found that technology can have a positive impact when used as part of a blended learning model, where it supplements traditional teaching methods rather than replacing them. This suggests that the negative impact of technology depends on how it is integrated into the curriculum and used by both students and teachers.

The State-level differences significantly impacted the education quality and learning outcomes possible because of the variations in economic development and difference in governance and policy implementation, Different levels of economically developed states invest differently in learning resources and teacher development that enhance the quality of education and student outcomes. For instance, Filmer & Pritchett (2001) emphasize the correlation between household wealth, state resources, and student performance, showing that students in wealthier regions have access to better learning environments, contributing to higher academic achievement. Moreover, State governments have varying levels of efficacy in implementing national education policies such as Right to Education, National Education Policy, or the Midday Meal Scheme. While they have been introduced nationally, the level of implementation and regulation varies, which negatively affects education quality. Studies by Kingdon & Banerji (2009) show that effective policy implementation at the state level is critical for improving student retention, learning outcomes, and access to quality education.

Model 4: Equity

Table 11: Results of Panel Data Regression Using Random Effects Model for Model 4

DV: EQ	Coefficient	P-Value
LandAvailable	.0002156	0.371
FunctionalElectricity	-4.83e-06	0.950
Playground	-.0002832	0.056*
ReadMat	.0002798	0.273
Furniture	-.0000514	0.446
FunctionalToiletandUrinal	.0000472	0.770
GirlTU	-.0003111	0.458
BoyTU	.000246	0.529
RainWaterHarvesting	-.0001202	0.538
PureWater	-.0000246	0.839
AddPhyFac	.0001874	0.071*
Med	.0000191	0.651
Tech	.000064	0.402
GP	.0277148	0.001***
Constant	87.29427	0.000

R-squared	0.6737	Number of obs	140

****p<0.01, **p<0.05, *p<0.1*

As seen in Table 11, the R^2 value is 0.6737 which means that 67.37 percent of the dependent variable – Equity – is explained by the 14 independent and 34 categorical State and Union Territory variables considered.

It's interesting to note that three categorical variables ate significant at 1 percent, three are significant at 5 percent, and two are significant at 2 percent. Also, all significant categorical variables negatively impacted EQ, signifying that the status of educational equity was worse in Arunachal Pradesh, Jammu and Kashmir, Kerala, Lakshadweep, Manipur, Meghalaya, Mizoram, and Odisha compared to State 9, Delhi.

Three of the 14 independent variables considered were significant. While AddPhyFac and GP affected EQ in a positive manner, Playground had a negative impact, as inferred from the coefficients. GP is significant at 1 percent while AddPhyFac and Playground are significant at 10 percent. Hence, the findings indicated that an increase in schools with the presence of additional physical facilities such as hand-rails and ramps and better systematic management and administration by the government will improve the state of equity. On the other hand, it's intriguing to observe that an increase in schools with playgrounds will have a negative impact on equity. Ultimately, this leads to the rejection of three null hypotheses: H_{3M4}, H_{11M4}, and H_{13M4}.

Additional physical facilities positively impact the state of equity in education. This can easily be explained because facilities such as ramps and hand-rails ensure accessible infrastructure for students

with disabilities. They help to ensure that all students can fully participate in the education system. Research by Schneider (2002) highlights that improved school facilities correlate with better student outcomes, especially in marginalized communities. Similarly, WestEd (2017) demonstrates that schools with inclusive infrastructure create more equitable environments by ensuring that students with physical disabilities and girls have the necessary facilities to participate fully in school. These findings are further supported by Barrett et al. (2015), which shows that school infrastructure improvements lead to better academic performance and increased enrolment for underprivileged students. However, Earthman (2004) argues that while physical facilities are important, they must be coupled with teacher effectiveness and learning resources to make a meaningful difference, suggesting that facilities alone may not be sufficient to close the equity gap.

Secondly, the governance processes, referring to the structured management of educational resources, accountability, and monitoring, also positive affect equity. This is because they also promote transparency and accountability to ensure that resources including funds, facilities, and teachers are allocated fairly and efficiently, particularly in underserved areas. This helps to reduce the learning gap for those from disadvantaged backgrounds or regions. Moreover, the focus on inclusivity by policies – such as the emphasis on enrolment and performance of marginalised groups – help ensure that students receive the necessary support to continue their education. Muralidharan & Sundararaman (2011) found that effective governance in teacher attendance and fund allocation directly led to better outcomes for students from disadvantaged communities. Additionally, Kingdon & Teal (2010) demonstrated that states with strong governance processes, particularly in teacher recruitment and accountability, witnessed improved educational outcomes among marginalized groups.

Playgrounds have a negative impact on equity. Although this is surprisingly, it can be explained due to the disproportionate benefit that they have for students residing in urban areas or from better economic backgrounds. The differences they cause in terms of accessibility and inclusivity may also worsen the equity. Research by Dyment & Bell (2008) found that schools in affluent areas are more likely to have well-maintained playgrounds, leading to better overall student engagement. Lareau & Weininger (2003) argue that students from disadvantaged backgrounds may not equally benefit from such facilities if they lack access to basic academic resources, further widening the resource gap. Additionally, PROBE (1999) highlights that focusing on non-academic facilities like playgrounds in underfunded schools can divert attention from more pressing needs, such as improving classroom resources and teacher training, thus negatively impacting equity.

The individual State and Union Territory level differences accounted for a significant difference in the equity across education. However, comparatively, with reference to the other three models, their impact was less significant. This indicated that while regional factors, such as State-level governance, may not affect equity, larger nation-wide factors account for a more significant impact. State and Union Territory differences significantly affect equity in education, particularly due to variations in governance, resource allocation, and local implementation of policies, as highlighted by Dahill-Brown (2019). However, research by Wilcox & Lawson (2022) emphasizes that nation-wide factors, such as federal funding and standardized programs, often have a broader and more significant impact on educational equity by setting uniform standards across regions. Kingdon & Teal (2010), however, argue that without effective state-level governance, national policies may not produce desired outcomes, suggesting that both levels play critical roles.

CONCLUSION

The aim of this study was the understand the impact of 14 resource-base determinants and State and Union Territory level differences on educational outcomes, proxied through four fundamental ways of enrolment, retention, learning outcomes and quality, and equity of the education system. The research, conducted using the 35 States of India from 2017 to 2020, underscores the complexity and holistic nature of educational outcomes. While certain factors such as governance processes help to improve educational outcomes, functional toilets and urinals, girls' toilets and urinals, and boys' toilets and urinals have no significant impact on any of the proxies of educational outcomes.

The summarised outcomes for all the independent variables have been shown below in Table _:

Table _: Summarized Results

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15
Enrolment			↑						↑		↓		↓		SIG
Retention														↑	SIG
Learning Outcomes and Quality		↑		↑	↑								↓		SIG
Equity			↓								↑			↑	SIG

[↑ represents a significant positive impact, ↓ symbolises a significant negative impact, SIG signifies a significant impact]

The results of the study have important implications for policymakers and academics in this field. Specifically, policymakers should prioritise the monitoring and supervision in the education system by the government. This has shown to have a significant positive impact in retention as well as equity, indicating its importance to educational outcomes. Policymakers should emphasise upon the implementation of systems, preferably digital, to improve transparency and accountability. Furthermore, it's important for the government to realise the precarious nature of playgrounds and additional physical facilities. While playgrounds attempt to improve the enrolment rate by highlighting the multifaceted approach to learning, they also reduce equity in the system. Moreover, while additional physical facilities often limit the enrolment rate, they help improve equity and inclusivity to all students, particularly designed for those facing physical disabilities. Policymakers should actively recognise the different nature and extent to impact of each of these variables in order to initiate tangible impact. For instance, introducing regulations and norms about the minimum number of librarians or access to newspapers and supplementary reading materials will help improve learning outcomes and quality. The consistent negative impact of technology is also important to note. While increased accessibility to computers and internet reduce enrolment and learning outcomes and quality, as supported from previous research, their integration into the pedagogy supported with a strong teaching background will help facilitate their positive impact.

The study also contributes to existing literature by highlighting the influence of contextual factors, recognized through the individual State and Union Territory level differences. It's important for the central (national) government to ensure nation-wise regulations to standardize the base quality of education which should then be furthers accentuated by regional State-level forces and policies. However, it's important to note that States' legislation should not be the base of education, due to the unregulated and uncontrolled impact they may cause. Additionally, the study, by focusing on the different States and Union Territories of a single nation, lays a strong foundation for policy formulation specific to India's

needs and development. Moreover, the methodology of panel-data analysis, compared to a cross-sectional study, allows for a more dynamic understanding of the educational outcomes. The use of Random Effects Regression Model accounts for the observable and unobservable differences, the methodological rigor by offering a more accurate understanding of resources over time. Ultimately, this research takes a new take on existing literature by emphasising upon the specificities of infrastructural developments.

However, the research has certain limitations. The vast socio-economic, cultural, and political diversity across India's States and Union Territories implies that findings may have a stronger and more specific impact, due to the presence of regional factors, in certain areas over others. A more granular regional analysis could provide deeper insights than what is achievable in a nationwide study. Additionally, data availability posed an obstacle because of which the time frame of the study was limited to only 4 years. A longer time frame would provide a more robust understanding of these variables over time. Further, certain external factors such as the COVID-19 pandemic – that took place during 2020 – impacted the education system but have not been individually analysed. Future research can improve the time duration of the study to get a better understanding of the variables over time. Moreover, variables such as _, _, and _, can be included in studies. This study underscores the holistic nature of educational outcomes, in terms of the dependent and independent variables considered, providing a foundation for policymakers for improving the quality of education.

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