EDUCATIONAL CONSUMPTION AND REGIONAL COMMUNICATION INFRASTRUCTURE: AN ANALYSIS USING CHINA'S PROVINCIAL PANEL DATA

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Abstract. This paper examines how regional communication infrastructure affects education price dynamics across China. Using an annual panel of six provinces-Jiangsu and Shandong (east), Henan and Hubei (central), and Sichuan and Gansu (west) from 1993 to 2023, the study ensures consistent series for the Education Consumer Price Index (EduCPI) and its subcomponents: education supplies, education services, and culture & entertainment. Communication infrastructure is measured as the logarithm of cultural, educational, broadcasting, and postal institutions (ln(Media)). Two-way fixed-effects regressions with Driscoll–Kraay standard errors control for GDP per capita, disposable income, and government education spending. Results show a small but significant positive effect of ln(Media) on overall EduCPI growth. Yet, the effects vary across categories: infrastructure expansion tends to lower prices for education supplies and culture & entertainment, but slightly raises service costs. Regional heterogeneity is evident-price-containment is stronger in eastern and central provinces, while short-term upward pressure appears in less developed western areas. Overall, communication infrastructure can both moderate and amplify education prices depending on consumption type and regional capacity. Policy should therefore combine infrastructure investment with supply-side improvements in lagging regions and network optimization in advanced ones.
Keywords: *communication infrastructure, education consumer price index, panel data regression, Driscoll–Kraay Standard Errors, regional heterogeneity*

Introduction

Recent advances in Internet and digital communication technologies have reshaped operations across many social sectors, including education, where online courses, digital textbooks, and live-streamed teaching have expanded rapidly and challenged traditional offline providers in channels and pricing decisions (Tan and Tasir, 2024). Education consumption prices, captured by the Education Consumer Price Index (EduCPI), display marked regional variation within China. Eastern coastal provinces with richer cultural and educational resources and denser media infrastructure often record faster growth in education prices than many central and western provinces. In less developed regions, gaps in fiscal capacity together with scarce communication channels can constrain movements in education supply prices and slow market responses (Fang, 2024). Prior studies mainly link macroeconomic conditions to education prices. Many confirm positive associations between development level and household income on the one hand and fluctuations in education prices on the other, while higher government education expenditure can ease household cost burdens to some extent (Yang and Wang, 2023). However, much of this work adopts fiscal and price or income and price perspectives and pays limited attention to how communication infrastructure moderates access,

information, and distribution in education services. Research on media accessibility and educational equity often focuses on Internet penetration and online resources, whereas traditional carriers such as cultural centers, broadcasting stations, and postal outlets remain underrepresented in measurement frameworks (Ni et al., 2022).

This study introduces a composite indicator based on the number of cultural, educational, broadcasting, and postal institutions as a proxy for regional communication infrastructure. The analysis makes three contributions. First, it integrates these institutions into a unified measure that captures regional infrastructure intensity. Second, it refines EduCPI into three subindices for education supplies, education services, and educational culture and entertainment to assess category-specific sensitivities. Third, it employs a long-run provincial panel for six representative provinces across eastern, central, and western China from 1993 to 2023 to examine spatial and temporal heterogeneity. This study has three research objectives. The first objective is to estimate the impact of regional communication infrastructure on the growth rate of EduCPI. The second objective is to identify heterogeneous responses across the three subindices. The third objective is to compare effects across eastern, central, and western provinces. To achieve these objectives, a two-way fixed-effects panel regression is estimated, where the main explanatory variable is the natural logarithm of the composite infrastructure measure and the controls are the logarithms of GDP per capita, disposable income per capita, and government education expenditure.

Literature review

Research on cultural education broadcasting and postal infrastructure

The cultural, educational, broadcasting, and postal system is a core part of communication infrastructure. Measurement commonly uses counts of institutions, outlet density, and fixed asset investment, with telecom indicators such as broadband subscribers and cellular IoT terminals to reflect coverage and intensity (National Bureau of Statistics of China, 2023). Joint guidance from the International Telecommunication Union and the Universal Postal Union shows that combined coverage and outlet counts after ICT integration are practical metrics for accessibility and service capacity across regions. From an information economics view, stronger infrastructure reduces search and transaction costs, shortens price transmission chains, and weakens intermediary mark ups, which pushes prices downward (Rogowski et al., 2022). Investment also heightens competition, speeds the exit of high-cost firms, and improves allocation efficiency and performance (Aghion and Schankerman, 1999). In cultural and educational markets, media channels shape preferences and willingness to pay, which can generate premiums for related goods and services (Kong et al., 2024). Coverage is uneven across provinces and between urban and rural areas. Differences in broadcasting and postal networks affect access to information and produce price asymmetries for textbooks, stationery, and training. Empirical work often applies logarithmic transformations and fixed effects panels to study these outcomes. Evidence from Chinese provinces links infrastructure disparities to development imbalances and shifts in household consumption, underscoring the role of communication capacity in diffusion and price formation (Kong et al., 2024; Gries and Redlin, 2009). Urban studies report strong east–centre–west differences and show that urban–rural gaps expose peripheral areas to information disadvantages that influence prices for public resources (Rogowski et al., 2022; Zhou and Zeng, 2013). Spatial panel results further indicate that

variation in transmission capacity yields uneven spatial price distributions for homogeneous goods such as housing, a mechanism that extends to educational goods and services (Kong et al., 2024). Together, these findings support the use of logarithmic variables with fixed effects to capture how communication capacity drives regional heterogeneity in educational consumption prices.

Empirical studies on the impact of educational consumption

Household spending on education, culture, and entertainment has risen in both urban and rural areas since the reform and opening up. Provincial data show rural shares increased from 5.1 percent in 1980 to 9.5 percent in 2014, and urban shares from 8.4 percent to 13.3 percent, indicating a larger role in aggregate demand (Zhao et al., 2023). Studies usually distinguish goods, services, and cultural education entertainment. In goods markets, e-commerce and logistics lower prices for standardised items such as textbooks, with stronger effects where outlets are denser (Liu, 2024). Targeted digital advertising further reshapes pricing, especially in highly urbanised areas (Xu and Zhang, 2022). In services, broader broadband access shifts users toward online content and reduces marginal dissemination costs, while many students rely on digital tutoring over longer periods, altering local pricing structures (Shi and Li, 2023; Song et al., 2021). Competition from online platforms raises pressure on offline training providers, prompting price adjustments (Studi, 2021). Cultural education entertainment depends on fiscal capacity, income, and infrastructure. Higher public spending is associated with stronger per capita consumption, while higher consumer prices can restrain growth; richer regions participate more deeply (Zhao et al., 2023). Traditional media can increase willingness to pay through embedded content value and brand effects, and social media broadens youth participation (Huang, 2021). Transport and communication upgrades capitalise into surrounding facility premiums that lift ticket and training costs in dense cultural districts, while e-commerce and express delivery widen reach and reduce access costs for books, artworks, and educational kits (Liu, 2024).

Application of fixed-effects and robustness tests

Empirical work on educational consumption and communication infrastructure commonly uses panel methods with fixed effects and a set of robustness checks. Provincial studies for China show how dissemination channels shape growth and consumption structure when fixed effects are combined with quantile or instrumental variable approaches, and they confirm stability through variable substitution within provincial panels (Zhang, 2018). More detailed designs trace dissemination and cognition pathways. Mediation regressions with two way fixed effects and multiple checks link health education information flows to insurance and food related education spending, while causal forest models capture heterogeneous responses under different income structures and media coverage (Gao et al., 2022). Methodological advances address data features such as nonlinearity and heteroscedasticity through robust loss functions and model inter regional dynamics with interactive fixed effects to reflect heterogeneous infrastructure impacts on price formation (He et al., 2023; Boudt and Heyndels, 2022). The literature therefore suggests that communication infrastructure can both restrain and stimulate prices by lowering information costs and intensifying competition, with downward pressure more visible for goods and with online and offline substitution shaping service prices. Regional comparisons often find stronger

price containment in developed eastern provinces and short run rebounds with lagged adjustment in less developed areas. Gaps remain on subcategory specific effects and on dynamic transmission paths by region. Building on these insights, the present study uses a two-way fixed effects model with Driscoll and Kraay standard errors to estimate the effect of ln(Media) on EduCPI growth, to assess the three subindices for goods, services, and culture and entertainment, and to compare eastern, central, and western provinces (He et al., 2023; Boudt and Heyndels, 2022; Gao et al., 2022; Zhang, 2018).

Materials and Methods

Application of fixed-effects and robustness tests

This study examines links between communication infrastructure, education consumption prices, and regional differences with provincial panel data and fixed effects methods (Cai et al., 2024). Cultural and educational facilities, radio and television networks, and postal systems help transmit market information and widen access to resources, which can move prices for supplies and services at the margin (Konyrbay et al., 2024; Xu, 2024). Heterogeneity is expected because development stages, fiscal capacity, and public resource allocation differ across regions (Gao et al., 2024). To capture timing and place effects, the analysis adds lags and runs subsamples for eastern, central, and western provinces (Li, 2024). The sample covers six provinces over 1993 to 2023 and provides complete series for a consistent panel.

Data sources and variable definitions

Data come from the China Statistical Yearbook for 1990 to 2023. Missing values are handled by linear interpolation and regression-based imputation to keep series continuous and comparable across provinces (Susetyo and Fitrianto, 2024). The main outcomes are the Education CPI and its three subindices for goods, services, and culture and entertainment. Communication infrastructure is proxied by the number of cultural, educational, broadcasting, television, and postal institutions. Controls are GDP per capita, disposable income per capita, and local fiscal education expenditure. The Education CPI indices use previous year equal to one hundred; year on year growth is obtained by subtracting one hundred as in prior practice (Supianti, 2023). All main variables are in natural logs to address scale differences and heteroskedasticity and to allow elasticity interpretation (Roosyidah et al., 2024; Han and Kim, 2023; Thobekile et al., 2023; Herwartz et al., 2022). A compact list of variable names, definitions, and units is provided in *Table 1*.

Table 1. *Variable list and definitions*

Variable Type	Meaning	Unit
Dependent Variable	Education CPI	Index (Base=100)
	Education Goods CPI	Index (Base=100)
	Education Services CPI	Index (Base=100)
	Education, Culture, and Entertainment CPI	Index (Base=100)
Independent Variable	Number of Cultural, Educational, Broadcasting, and Postal Systems	Count
Control Variable	Per Capita GDP	CNY per person
	Per Capita Disposable Income	CNY
	Local Government Education Expenditure	CNY 100 million

Panel regression model specification

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A two-way fixed effects model with province and year effects is estimated. The dependent variable is the growth rate of the Education Consumer Price Index. The key regressor is the natural logarithm of the number of cultural, educational, broadcasting, and postal institutions. Controls are the natural logarithms of GDP per capita, disposable income, and local government education expenditure. The baseline specification is (Eq. (1):

$$y_{it}=\alpha_i + \beta 1 lnMedia_{it} + \beta 2 lnGDPpc_{it} + \beta 3 lnIncome_{it} + \beta 4 lnEduExpend_{it} + \gamma_t + \varepsilon_{it} \quad \text{Eq. (1)}$$

Where i indexes provinces and t denotes year t (1993-2023). α_i is the province effect and γ_t is the year effect. Subindices for education goods, education services, and culture and entertainment are estimated in the same way with the same set of controls. Details of the within transformation are provided in the appendix (Arkhangelsky et al., 2024; Dou and Yin, 2024; De Monte, 2023).

Robustness checks

Standard errors follow Driscoll and Kraay to address serial correlation, heteroskedasticity, and cross-sectional dependence in long panels with few units. The correction is applied to the baseline and to all subindex models. The estimator and bandwidth choice are documented in the appendix with formulas and references (Mahwish et al., 2023; Parsons, 2023; Parsons and Naghshpour, 2023; Emenekwe and Emodi, 2022).

Provincial comparison analysis

Province specific regressions use ordinary least squares with Driscoll and Kraay standard errors and the same specification as the baseline. Results report the elasticity of ln(Media) and confidence intervals for each province. Full estimates and diagnostics are included in the appendix (El Shagi and Tochkov, 2024; Ul Haq et al., 2023).

Results and Discussion

Overall regression results of the main model

Controlling for ln(GDPpc), ln(Income) and ln(EduExpend), the effect of ln(Media) on the growth rate of Education CPI is positive and significant with Driscoll and Kraay standard errors (*Table 2*). The key coefficients are: ln(Media) 0.0218 with p = 0.0186; ln(GDPpc) 0.9532 with p < 0.0001; ln(Income) −0.9341 with p < 0.0001; ln(EduExpend) 0.1212 with p < 0.0001. These results suggest that economic development raises education prices, higher incomes tend to restrain price growth through competition, and public education spending is price increasing. The small but significant ln(Media) effect implies that more developed media and education infrastructure can lift demand and prices in the short run, consistent with market dynamics noted in recent evidence on education consumption (Zhao et al., 2023).

Table 2. *Main model regression results (ΔEduCPI, Driscoll–Kraay Standard Errors).*

Variable	Coefficient	SE_DK	t-Value	p-Value
ln(Media)	0.0218	0.0092	2.38	0.0186
logGDPpc	0.9532	0.0581	16.4	<0.0001

Subcategory model regression results

All subcategory models use Driscoll and Kraay standard errors and the same controls. Education goods. ln(Media) is −0.5366 with $p < 0.0001$, indicating a strong suppressive effect on education goods price growth. ln(GDPpc), ln(Income) and ln(EduExpend) are positive and significant, with income and fiscal spending as main drivers of goods prices. These patterns mirror demand expansion for higher end materials and devices when income and budgets rise (Zhao et al., 2023). These patterns are consistent with the full results in *Table 3* and confirm strong containment of goods prices.

Table 3. *Regression results for the growth rate of CPI for educational supplies (Driscoll–Kraay Standard Errors).*

Variable	Coefficient	SE_DK	t-Value	p-Value
ln(Media)	-0.5366	0.0277	-19.38	<0.0001
logGDPpc	3.1432	0.2875	10.93	<0.0001
logIncome	25.445	1.0817	23.52	<0.0001
logEduExp	5.1415	0.1294	39.73	<0.0001

Education services. ln(Media) is 0.0163 with $p = 0.0614$. The effect is small and only marginally significant. ln(GDPpc) 0.8786 and ln(EduExpend) 0.1180 are positive and highly significant. ln(Income) is −0.8589 and highly significant, suggesting that richer areas have more supply and slower price growth in services, in line with recent studies of service markets and platform competition (Ying and Peng, 2022). The complete set of service coefficients in *Table 4* supports this limited short run effect.

Table 4. *Regression results for the growth rate of CPI for educational services (Driscoll–Kraay Standard Errors).*

Variable	Coefficient	SE_DK	t-Value	p-Value
ln(Media)	0.0163	0.0086	1.89	0.0614
logGDPpc	0.8786	0.0555	15.84	<0.0001
logIncome	-0.8589	0.0718	-11.96	<0.0001
logEduExp	0.118	0.0094	12.54	<0.0001

Culture and entertainment. ln(Media) is −0.0390 with $p < 0.0001$, showing a clear dampening effect on price growth. ln(Income) 3.9991 and ln(EduExpend) 0.4972 are large and significant, while ln(GDPpc) 0.6075 is positive with moderate elasticity. Income and fiscal spending are therefore the main drivers; media infrastructure eases price pressure by improving information flow and access (Yang and Wang, 2023). This interpretation aligns with the detailed coefficients reported in *Table 5*.

Table 5. *Regression results for the growth rate of CPI for educational cultural and entertainment goods (Driscoll–Kraay Standard Errors).*

Variable	Coefficient	SE_DK	t-Value	p-Value
ln(Media)	-0.039	0.0056	-6.97	<0.0001
logGDPpc	0.6075	0.047	12.94	<0.0001
logIncome	3.9991	0.196	20.4	<0.0001
logEduExp	0.4972	0.0202	24.67	<0.0001

As shown in *Table 6*, the inhibitory effect is strongest for goods, is clear but smaller for culture and entertainment, and is weak and unstable for services. The summary of ln(Media) coefficients is: goods −0.5366; services 0.0163; culture and entertainment −0.0390. This ranking indicates that improved communication infrastructure constrains

physical goods prices most, while service prices respond mainly to broader development and budget conditions.

***Table 6**. Summary of ln(Media) coefficients for three sub-models.*

Category	ln(Media) Coef	SE_DK	t-Value	p-Value
EduGoodsCPI	-0.5366	0.0277	-19.38	<0.0001
EduServCPI	0.0163	0.0086	1.89	0.0614
EduCultureCPI	-0.039	0.0056	-6.97	<0.0001

The effects differ across categories. Education goods are most sensitive. A one percent rise in ln(Media) lowers the goods CPI growth by about 0.5366 percentage points and the effect is highly significant. The services coefficient is small and only marginally significant, which points to a limited and unstable short term impact. The culture and entertainment coefficient is negative and significant, showing a clear but smaller dampening effect than for goods. Overall, infrastructure restrains goods prices most, curbs culture and entertainment to a lesser extent, and has a weak effect on services.

Provincial heterogeneity analysis

As shown in *Table 7*, the pattern aligns with regional capacity. Eastern provinces cluster near −0.06, which indicates modest additional containment under near saturation. Henan presents a large negative elasticity, reflecting strong gains from improved information symmetry. Sichuan records the strongest suppression from a low base. Gansu is positive and significant, which is consistent with demand outpacing supply where educational and communication bases are very weak. *Figure 1* provides a visual summary with 95 percent intervals.

***Table 7**. Summary of ln(Media) Coefficients for Three Sub-models.*

ProvinceID	Coefficient	SE_DK	t-Value	p-Value	95% Confidence Interval	Region
1	-0.055	0.0111	-4.94	<0.0001	[-0.0768, -0.0332]	Eastern
2	-0.063	0.0021	-29.67	<0.0001	[-0.0671, -0.0590]	Eastern
3	-0.5093	0.0449	-11.34	<0.0001	[-0.5984, -0.4202]	Central
4	-0.0501	0.0066	-7.55	<0.0001	[-0.0629, -0.0373]	Central
5	-1.5673	0.0266	-58.82	<0.0001	[-1.6194, -1.5152]	Western
6	0.1007	0.0126	8.01	<0.0001	[0.0877, 0.1137]	Western

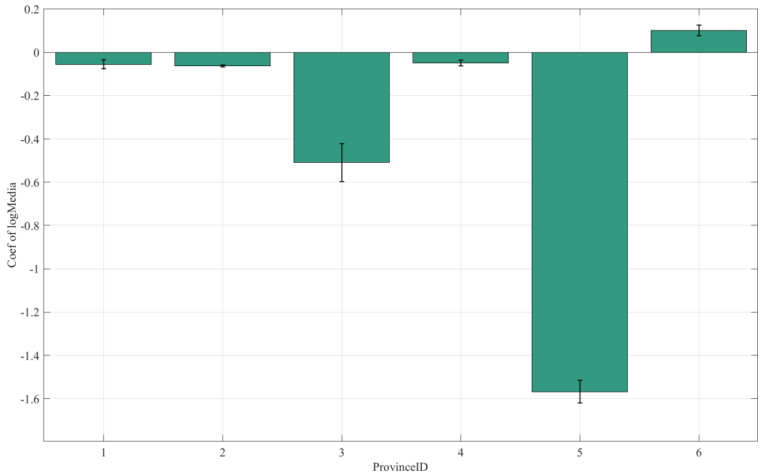

***Figure 1.** Provincial coefficients of ln(Media) on ΔEduCPI (95% confidence intervals).*

Conclusion

This study uses panel data for six provinces from 1993 to 2023. It estimates two way fixed effects models with Driscoll and Kraay corrections. The results show a small but significant positive link between communication infrastructure and the overall growth of the Education Consumer Price Index. The composite measure based on cultural, educational, broadcasting, and postal institutions is associated with a modest rise in aggregate education prices after accounting for macroeconomic and fiscal controls. Category level estimates are not uniform. Expansion of communication infrastructure is linked to lower growth in the education supplies index. It is also linked to lower growth in the culture and entertainment index. The education services index shows a slight positive response, which is consistent with wider access and more variety in services in the short run. Regional patterns are clear. Eastern provinces and Hubei display modest inhibitory effects near five hundredths in absolute value. Henan and Sichuan show larger inhibitory effects close to one half and one and a half. Gansu shows a small positive elasticity. This pattern suggests that very weak starting conditions can lead to temporary price increases when demand reacts faster than supply. These findings are consistent with recent work on uneven development and price dynamics in education markets (Liu, 2023; Mo, 2023). Taken together, the study measures the overall effect, compares categories, and examines regional differences. The evidence meets the aims set out in the introduction and supports a nuanced view of how communication infrastructure and education prices coevolve.

For eastern and central developed regions, shift effort from expansion to optimisation. Improve the coverage and reliability of online provision. Strengthen remote teaching platforms. Invest in teacher training so that existing networks deliver higher instructional quality. These steps help stabilise education prices and reduce the risk of diminishing returns from further network growth. For underdeveloped central and western regions, continue to invest in communication infrastructure to close information gaps and lower access costs. Expand the supply of educational services through targeted subsidies and predictable public finance. Widen broadband access. Build township multimedia classrooms. Ensure that school capacity grows with the network so that short term price rebounds are avoided. For areas with very weak bases such as parts of Gansu, balance infrastructure with quality improvement. Provide coordinated fiscal support from central and provincial levels. Create incentives for qualified teachers to serve rural and remote communities. Offer continuous professional development with clear performance evaluation. A twin track approach that builds networks and school capacity reduces supply and demand mismatches and supports stable and equitable access to education (Liu, 2023; Mo, 2023).

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Conflict of interest

The authors confirm that there is no conflict of interest involving any parties in this research study.

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