Road expansion, allocative efficiency, and pro-competitive effect of transport infrastructure: Evidence from China

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Road expansion, allocative efficiency, and pro-competitive effect of transport infrastructure: Evidence from China☆

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ABSTRACT

This paper exploits the rapid expansion of China's road infrastructure in the 2000s to empirically investigate the pro-competitive effect of transport infrastructure via the allocative efficiency channel. Dispersion of firm markups is used to gauge allocative efficiency of resources. We address the endogenous provincial road length by instrumenting road using a least-cost path route, and deal with the endogenous timing of road construction by using a network theory algorithm to predict road construction time. Our results show the mass construction of new road infrastructure, by lowering domestic trade costs, can significantly reduce markup dispersion of industries with high reliance on transportation. The baseline estimation indicates that the road expansion in China during 1998–2007 has induced at least 28.8% reduction in markup dispersion. Further analysis by disentangling price and marginal cost indicates that the reduced markup dispersion is primarily caused by the price drop of high-markup firms in the product market instead of cost reduction in the input market. This finding validates the presence of pro-competitive effect of road infrastructure. The heterogeneous analyses show several scenarios in which market competition is strengthened and the pro-competitive effect is more clearly manifested.

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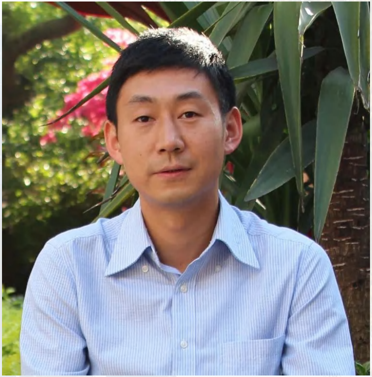

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- Beyond the collateral channel: Real estate prices and manufacturing firm investment in China (with Yan Wu and Nico Heerink), ***International Review of Economics and Finance*** (2024), 94: 103352.
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Economists and policy makers widely believe that transport infrastructure investment plays an important role in promoting economic development.

This paper conducts reduced-form empirical exercises to examine:

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- Whether road infrastructure improvement can reduce markup dispersion ?
- And thus, enhance allocative efficiency and generate pro-competitive gains.

Review

Improved transport infrastructure can reduce trade cost, thereby narrowing down the interregional price gap and increasing interregional trade flows, which eventually brings about improved trading environment, enhanced market integration, and additional large economic welfare.
The previous literature has attributed the welfare gains from trade to two major channels.

The First Channel

Productive efficiency from the classical *Ricardian* effect of trade if all firms charge their marginal cost.

The Second Channel

Allocative efficiency from the pro-competitive effect of trade, particularly, efficiency and productivity losses due to resource misallocation in an imperfect competitive market can be reduced if firms are exposed to more head-to-head competition

The allocative efficiency channel has not received sufficient attention in trade literature until recently and still lacks a rigorous empirical analysis.

Empirical way

This study contributes to the literature by focusing on the **allocative efficiency channel** that is understudied empirically thus far.

- Exploiting the rapid expansion of China's road infrastructure in the 2000s to investigate the pro-competitive effect of transport infrastructure.

For identification:

Empirical way

This study contributes to the literature by focusing on the **allocative efficiency channel** that is understudied empirically thus far.

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For identification:

- They exploit the heterogeneity of road length in China's provinces and the differences in transport reliance of Chinese manufacturing industries.
- They estimate a "difference-in-differences" specification, in which they compare industries that are more reliant on transportation (the treatment group) with those that are less reliant on transportation (the control group) before and after the yearly differential accumulation of road infrastructure in their respective provinces.

The key mechanism

To empirically identify the pro-competitive effect of road infrastructure, it is essential to understand the key mechanism of what exactly roads do to change allocative efficiency.

- First, it is well established in literature that firms with high markups employ less production resources and thus produce less than its optimal level (i.e., the level when price equals marginal costs). Accordingly, markup dispersion induces an inefficient allocation of resources across producers (misallocation) and welfare loss, e.g., lower aggregate total factor productivity (TFP).
- Second, improvement in transport infrastructure decreases the output prices of firms in product markets by introducing more competition from reduced domestic trade costs. It also lowers the marginal costs of firms because of cheaper input prices and lower transportation costs.
- Consequently, it affects firm markup and markup distribution and thus the allocative efficiency. Note that allocative efficiency is determined by how the production resources are allocated across firms with different markups.

In short, in an economy with markups dispersion, transportation infrastructure may improve allocative efficiency if it can condense the dispersion of markups.

Two different effects

According to definition $markup = \frac{P}{MC}$,
improved road infrastructure may

- **reduce firm markup and condense markup dispersion** by promoting greater competition in product market
- **increase firm markup and expend markup dispersion** by reducing the marginal costs of firms

To clearly identify the impact of road infrastructure on allocative efficiency, it is thus important to disentangle the price and cost channels.

Contribution & Literature

- The first empirical work that rigorously analyzes the pro-competitive effect of transport infrastructure via allocative efficiency channel using the precisely estimated firm markups.
- Closely related to *Asturias et al. (2019)*, who has done a similar work by quantifying the components of welfare effect of transportation infrastructure in the context of India on the basis of the framework developed by *Holmes et al. (2014)*.This papaer's measure of markup dispersion is recognized in the trade literature as a more accurate and direct approach of reflecting allocative efficiency and the pro-competitive effect of trade.
- Related to the broad literature on trade and transport infrastructure *(e.g., Hummels and Schaur, 2013; Duranton et al., 2014)*, particularly the recent empirical work that relies on improvements in connectivity due to investment in transport infrastructure, which is measured by changes in a location' s market access *(e.g., Donaldson and Hornbeck, 2016; Baum-Snow et al., 2020; Fiorini et al., 2021; Jedwab and Storeygard, 2022)*. Market access is a summary measure constructed by a weighted aggregation of the bilateral connectivity of an urban area (e.g., city, county or town) with all other urban markets in the country.

Contribution & Literature

- Also relevant to the extensive literature on the economic effects of transport infrastructure. Beginning with *Aschauer (1989)*, some studies have examined a wide range of the macroeconomic outcomes of transport infrastructure such as GDP *(e.g., Démurger, 2001; Banerjee et al., 2020)*, local economic development *(Asher and Novosad, 2020)*, trade flow *(e.g., Li and Chen, 2013)*, city growth *(e.g., Duranton and Turner, 2012)*, employment and establishment *(Frye, 2022)*, and urban structure (*e.g., Storeygard, 2013; Baum-Snow et al., 2017a,b*). Other studies have looked into the microeconomic effects of transport infrastructure, including firm inventory *(Shirley and Clifford, 2004; Li and Li, 2013)*, firm productivity *(Li et al., 2017; Yang, 2018; Davis and Qian, 2020; Lu, 2021)*, return to capital *(Bai and Qian, 2010)*, and skill premium in the labor market *(Michaels, 2008)*.
- Although most studies find positive effects of transport infrastructure, *Faber (2014) and Qin (2017)*, on the basis of Chinese data, find that better transport connections produce negative effects on the GDP growth of the peripheral counties along the connecting route because of reduced industrial output growth or fixed asset investment in these peripheral regions.

2.1 Road infrastructure expansion in China

- Road infrastructure investment in China has increased from below 2% of GDP in the mid-1990s to approximately 6% by the mid-2000s.
- The total road length in China was 4.57 million km in 2015, i.e., four times more than the length in 1980. The annual growth rate of roads is 14% from 1998 to 2015

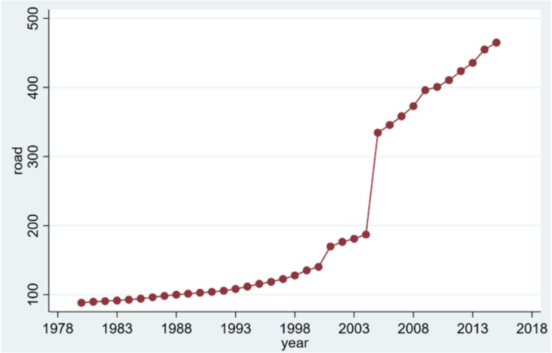
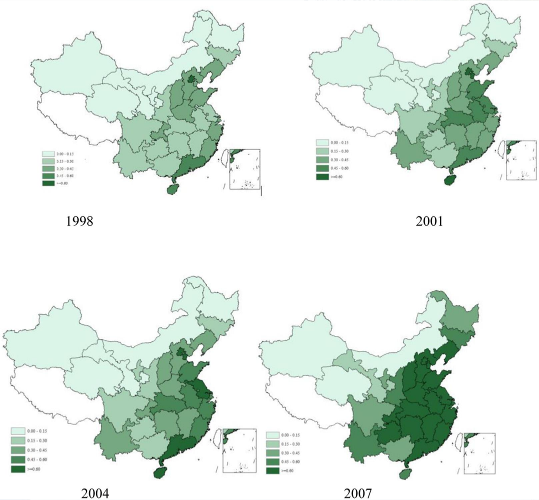


图 1: Road length in China during 1980–2015. Notes: The unit of road length is 10,000 km. Source: Data source: China Statistical Yearbook, 1980–2015.

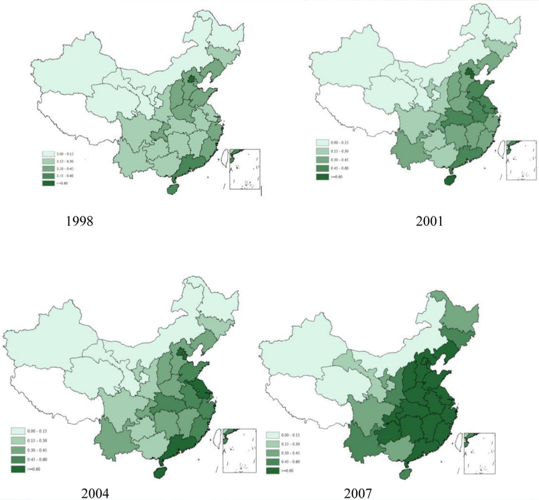
Regional distribution and growth of roads

- The legend on China's map shows road density divided into quintiles. The four panels represent the year 1998, 2001, 2004 and 2007, i.e., they show the changes every three years during our sample period of 1998–2007.



Regional distribution and growth of roads

- The legend on China's map shows road density divided into quintiles. The four panels represent the year 1998, 2001, 2004 and 2007, i.e., they show the changes every three years during our sample period of 1998–2007.
- Roads then experienced a rapid but uneven growth in the subsequent years, i.e., they grew faster in the east and central provinces that are closer to the coast, but grew slower in western regions far from the ocean.



2.2. Misallocation and cross-region industry competition

The construction of roads can reduce domestic trade cost and increase intraregional and interregional trade, generating procompetitive gains through reduced markup distortion and improved allocative efficiency.

The allocative efficiency channel only works if the following two conditions are satisfied.(Edmond et al. 2015),

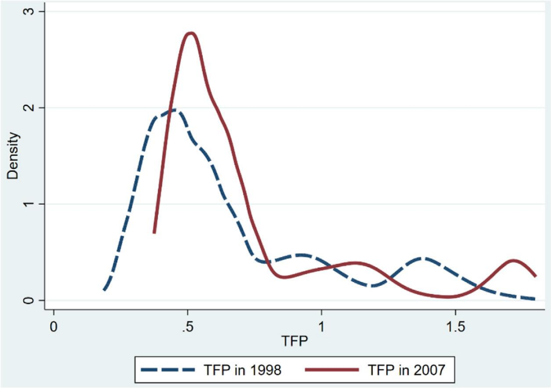
- First, extensive misallocation must exist;
- second, producers from different regions in the same industry must have similar productivities to compete head-to-head.

Therefore, checking whether these two conditions are satisfied is essential in our research setting of China before proceeding with regression analysis.

TFP distribution

Fig. 3 depicts the distribution of TFPs of Chinese manufacturing firms in 1998 (the year before the large-scale construction of new roads) and 2007 (the year after the large-scale construction of new roads).

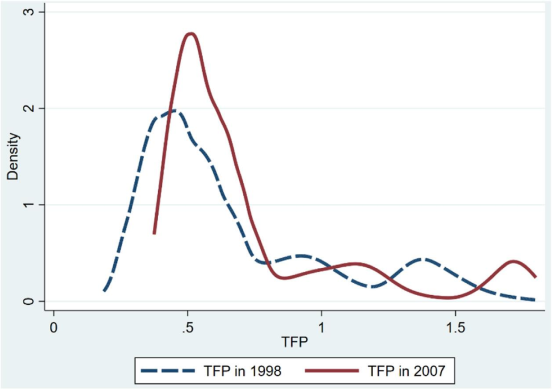
This figure simply provides a rough picture of the initial degree and evolution of overall misallocation in China as reflected by firm TFP dispersion.



TFP distribution

First, TFP distributions are highly skewed to the right in both years; moreover, TFPs are visually more dispersed in 1998 than in 2007, suggesting a relatively larger initial misallocation of resources in China before the mass construction of new roads than thereafter.

Second, the aggregate TFP (in logarithmic form) has increased from 0.669 in 1998 to 0.739 in 2007, indicating a substantial productivity gains along with the observed reduction in resource misallocation.



First Condition

TFP dispersion is much larger in 1998 than in 2007 for all provinces (regardless of their road density) and all industries (regardless of their degree of reliance on transport) as reflected by all five indices of dispersion:

Table 1
Misallocation and allocative efficiency in China (1998 versus 2007)

		Panel A: Misallocation across regions and industries					
		Province road density (1998)			Industry road reliance		
		High	Low	Diff. (High vs. Low)	High	Low	Diff. (High vs. Low)
TFP dispersion (1998)	Theil	0.1230	0.1039	0.019**	0.0105	0.0117	−0.001
	MLD	0.1306	0.1085	0.022***	0.0096	0.0109	−0.001
	RMD	0.2186	0.2045	0.014*	0.0461	0.0506	−0.005*
	CV	0.4978	0.4581	0.040*	0.1349	0.1421	−0.007
	GINI	0.2793	0.2561	0.023**	0.0630	0.0690	−0.006*
TFP dispersion (2007)	Theil	0.1008	0.0972	0.004	0.0039	0.0058	−0.002*
	MLD	0.1044	0.1014	0.003	0.0037	0.0057	−0.002*
	RMD	0.2105	0.2085	0.002	0.0280	0.0354	−0.007***
	CV	0.4505	0.4405	0.010	0.0762	0.0938	−0.018***
	GINI	0.2407	0.2352	0.006	0.0378	0.0478	−0.010***
Diff. (1998 vs. 2007)	Theil	−0.0221**	−0.0067		−0.0066***	−0.0060***	
	MLD	−0.0261***	−0.0071		−0.0059***	−0.0052***	
	RMD	−0.0081	0.0040		−0.0181***	−0.0152***	
	CV	−0.0472**	−0.0179		−0.0587***	−0.0064*	
	GINI	−0.0386***	−0.0209***		−0.0253***	−0.0212***	

Given these facts, we argue that substantial misallocation already exists in China across regions and industries before the mass construction of roads, and thus, the first condition is satisfied.

Second Condition

TFPs are highly similar between inland and coastal region for most of the industries, on average, or even at different quantiles.10 Moreover, the correlation of sectoral mean productivity between coastal and inland regions is as high as 0.99, indicating minimal cross-region variation in producers' productivity.

Table A2. Percentile distribution of firm TFP by industry in China's coastal and inland regions

			Coastal						Inland			
Two-digit CIC	p10	p25	p50	p75	p90	mean	p10	p25	p50	p75	p90	mean
13	0.6697	0.7026	0.7351	0.7688	0.8060	0.7351	0.6605	0.6985	0.7307	0.7647	0.8005	0.7307
14	0.5236	0.5713	0.6566	0.7080	0.7446	0.6566	0.5223	0.5702	0.6542	0.7091	0.7478	0.6542
15	1.1637	1.2340	1.3455	1.4551	1.5705	1.3455	1.1288	1.1952	1.3041	1.4183	1.5271	1.3041
17	0.3374	0.3713	0.4241	0.4592	0.4919	0.4241	0.3443	0.3753	0.4292	0.4679	0.5166	0.4292
18	0.8760	0.9624	1.0589	1.1537	1.2443	1.0589	0.8355	0.9366	1.0426	1.1512	1.2482	1.0426
19	0.4330	0.4533	0.5207	0.5564	0.5832	0.5207	0.4353	0.4588	0.5189	0.5582	0.5955	0.5189
20	1.2955	1.4226	1.7704	1.9874	2.0583	1.7704	1.2091	1.3550	1.6763	1.9804	2.0461	1.6763
21	1.5104	1.6825	1.8663	1.9812	2.0919	1.8663	1.4248	1.5285	1.7948	1.9415	2.0612	1.7948
22	1.3514	1.4181	1.5506	1.6622	1.7784	1.5506	1.3177	1.3642	1.4794	1.6157	1.7251	1.4794
23	1.2681	1.3773	1.5572	1.7134	1.8264	1.5572	1.1592	1.2400	1.3847	1.6144	1.7683	1.3847
24	0.8735	0.9250	1.0572	1.1473	1.2109	1.0572	0.8624	0.9308	1.0859	1.1841	1.3469	1.0859
25	1.1083	1.2637	1.4595	1.6568	1.8320	1.4595	0.9564	1.0901	1.2296	1.3907	1.5710	1.2296
26	0.5492	0.5729	0.6042	0.6277	0.6682	0.6042	0.5500	0.5735	0.6054	0.6345	0.6930	0.6054
27	0.6290	0.7412	0.9129	1.0933	1.2131	0.9129	0.5847	0.6857	0.8466	1.0345	1.1638	0.8466
28	0.4654	0.5010	0.5391	0.5725	0.6100	0.5391	0.4669	0.5016	0.5327	0.5737	0.6148	0.5327
29	0.2576	0.3108	0.4358	0.4691	0.5187	0.4358	0.2641	0.3162	0.4328	0.4827	0.5576	0.4328
30	1.4634	1.6005	1.8128	1.9327	2.0495	1.8128	1.4150	1.4905	1.7368	1.8863	2.0014	1.7368
31	1.2974	1.3931	1.6076	1.7487	1.8536	1.6076	1.2510	1.3106	1.5078	1.6861	1.7994	1.5078
32	0.4294	0.4676	0.4902	0.5110	0.5441	0.4902	0.4264	0.4668	0.4888	0.5164	0.5627	0.4888
33	1.0801	1.2113	1.3611	1.5236	1.6845	1.3611	0.9935	1.1118	1.2502	1.3930	1.5479	1.2502
34	0.4158	0.4498	0.4848	0.5185	0.5860	0.4848	0.4194	0.4554	0.4939	0.5393	0.6613	0.4939
35	0.3050	0.3436	0.4030	0.4431	0.4766	0.4030	0.3149	0.3573	0.4122	0.4566	0.5127	0.4122

In summary, the second condition is also satisfied in our research context in China.

3.1 Data

- The first dataset is the total road length of China's provinces obtained from China Statistical Yearbooks compiled by the National Bureau of Statistics of China (NBSC). Road length is measured at the end of each year, while roads that are used for testing but not open for general use are excluded.
- The second dataset is the Annual Survey of Industrial Firms (ASIF), which was conducted by NBSC for the period of 1998–2007. This dataset reports comprehensive firm information on registration, operation, production, and financial performance, including industry, location, output, value-added, intermediate materials, employment, and book and net values of fixed assets, which are essential for estimating the production function, recovering firm markup, and calculating markup dispersion. This information is essential for easily identifying a firm's location and
- The third data comprises the input–output (IO) table of the U.S. published by the Bureau of Economic Analysis (BEA) in the version of the North American Industry Classification System (NAICS) 2007, which is used to calculate the transport reliance rate of each finely defined industry.

3.2 Variables

3.2.1 Firm Markup

- Markup is defined as the ratio of price over marginal costs.
- However, the firms in dataset report neither price nor marginal cost of their products.
- They strictly follow the framework of De Loecker and Warzynski (2012) and De Loecker et al. (2016) in estimating the firmlevel markups.

Assuming that the production function of firm i at time t is

$$Q_{it} = F_{it}(L_{it}, K_{it}, M_{it}, \varpi_{it})$$

- L_{it}**: physical input of labor**
- K_{it}**: physical input of capital**
- M_{it}**: intermediate materials**
- ϖ_{it} **is firm specific productivity.**

Production function $F(\cdot)$ is assumed to **be continuous and twice-differentiable** with respect to all of its arguments. This assumption assures that firm cost minimization can be solved under static first-order conditions with respect to labor, capital, and material input

3.2.1 Firm Markup

Set up

Cost minimization problem: for firm i at time t

$$\min_{\{L_{it}, K_{it}, M_{it}\}} \quad w_{it}L_{it} + r_{it}K_{it} + P_{it}^{m}M_{it}$$

$$s.t. \quad F_{it}(L_{it}, K_{it}, M_{it}, \varpi_{it}) \geq \overline{Q}_{it} \tag{1}$$

$$L_{it} \geq I[D_{it} = 1]\bar{E}_{it}$$

- w_{it} : wage rate
- r_{it} : rental price of capital
- P_{it}^{m} :price of intermediate materials
- D_{it} : a dummy variable that indicates whether a firm is a SOE or non-SOE;
- $I[.]$ is an indicator function that takes a value of one if the statement in the bracket is true and zero if not

Lagrangian function

$$
\begin{aligned}
L(L_{it}, K_{it}, M_{it}, \lambda_{it}, \pi_{it}) = & \; w_{it} L_{it} + r_{it} K_{it} + P_{it}^{m} M_{it} \\
& + \lambda_{it} [\overline{Q}_{it} - F_{it}(L_{it}, K_{it}, M_{it}, \varpi_{it})] \\
& + \pi_{it} [I[D_{it} = 1] \bar{E}_{it} - L_{it}]
\end{aligned}
\quad (2)
$$

First-order condition on materials input M_{it}.

$$
\frac{\partial L}{\partial M_{it}} = P_{it}^{m} - \lambda_{it} \frac{\partial F_{it}}{\partial M_{it}} = 0 \quad (3)
$$

Arranging and multiplying both sides by $\frac{M_{it}}{Q_{it}}$, ande arrange the above equation and multiply both sides by $\frac{M_{it}}{Q_{it}}$, ande consequently derive the following:

$$
\frac{\partial F_{it} M_{it}}{\partial M_{it} Q_{it}} = \frac{P_{it} P_{it}^{m} M_{it}}{\lambda_{it} P_{it} Q_{it}}. \quad (4)
$$

By rearranging the above equation, we can obtain firm markup, which is defined as the ratio of price over marginal cost.

$$
markup_{it} = \frac{P_{it}}{\lambda_{it}} = \frac{\partial F_{it} M_{it}}{\partial M_{it} Q_{it}} / \frac{P_{it} M_{it}}{P_{it} Q_{it}} = \frac{\theta_{it}^{m}}{\alpha_{it}^{m}} \quad (5)
$$

Estimate

To estimate the production function and acquire θ_{it}^{m}, they use the Translog production function, i.e.,

$$\begin{aligned} q_{it} = {} & \beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it} + \beta_{ll} l_{it}^2 + \beta_{kk} k_{it}^2 + \beta_{mm} m_{it}^2 + \beta_{lk} l_{it} k_{it} \\ & + \beta_{km} k_{it} m_{it} + \beta_{lm} l_{it} m_{it} + \beta_{lkm} l_{it} k_{it} m_{it} + \omega_{it} + \epsilon_{it} \end{aligned} \tag{6}$$

the lowercase letters represent the logarithm of the uppercase letters, ω_{it} is firm-specific productivity, and ϵ_{it} is an independent and identically distributed error term.

They separately estimate the Translog production function for each two-digit industry and calculate the output elasticity of materials as follows:

$$\theta_{it}^{m} = \widehat{\beta}_m + 2\widehat{\beta}_{mm} m_{it} + \widehat{\beta}_{lm} l_{it} + \widehat{\beta}_{km} k_{it} + \widehat{\beta}_{lmk} l_{it} k_{it} \tag{7}$$

With the estimated θ_{it}^{m}, we can readily calculate firm markups according to Eq. (5).

3.2.2. Markup dispersion

They use several methods to measure markup dispersion. The baseline method is the Theil index:

$$Theil_{sjt} = \frac{1}{n_{sjt}} \sum_{i=1}^{n_{sjt}} \frac{y_{isjt}}{\overline{y}_{sjt}} \log(\frac{y_{isjt}}{\overline{y}_{sjt}}) \quad (8)$$

where y_{isjt} is the estimated markup of firm i in industry s, location j, and time t; $\overline{y}_{sjt}$ and n_{sjt} are the average markup and number of firms in industry s, location j, and time t, respectively.

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Several alternative measures are employed as robustness checks.

- The first measure is MLD

$$MLD_{sjt} = \frac{1}{n_{sjt}} \sum_{i=1}^{n_{sjt}} \log(\frac{y_{isjt}}{\overline{y}_{sjt}}) \tag{9}$$

- The second is CV:

$$CV_{sjt} = \frac{\sqrt{V_{sjt}}}{\overline{y}_{sjt}} \tag{10}$$

- The third is RMD:

$$RMD_{sjt} = \frac{1}{n_{sjt}} \sum_{i=1}^{n_{sjt}} |\frac{y_{isjt}}{\overline{y}_{sjt}} - 1| \tag{11}$$

Markup dispersion

Table 2
Markup dispersion and transport reliance rate of Chinese manufacturing industries (**two-digit CIC**)

Two-digit CIC	Theil	MLD	CV	RMD	GINI	Road reliance rate
13	0.0087	0.0085	0.1495	0.0443	0.0575	0.0908
14	0.0061	0.0059	0.1357	0.0341	0.0412	0.0758
15	0.0085	0.0085	0.1544	0.0443	0.0557	0.0608
17	0.0078	0.0078	0.1462	0.0419	0.0542	0.0535
18	0.0110	0.0102	0.1593	0.0488	0.0636	0.0554
19	0.0079	0.0080	0.1504	0.0421	0.0532	0.0577
20	0.0092	0.0089	0.1509	0.0459	0.0587	0.0786
21	0.0101	0.0102	0.1707	0.0475	0.0607	0.0076
22	0.0083	0.0084	0.1431	0.0458	0.0609	0.0794
23	0.0121	0.0120	0.1693	0.0564	0.0751	0.0308
24	0.0058	0.0058	0.1332	0.0337	0.0419	0.0534
25	0.0082	0.0082	0.1399	0.0456	0.0589	0.0552
26	0.0079	0.0079	0.1465	0.0431	0.0548	0.0516
28	0.0103	0.0105	0.1969	0.0446	0.0541	0.0672
29	0.0076	0.0077	0.1498	0.0411	0.0517	0.0490
30	0.0112	0.0113	0.1608	0.0550	0.0724	0.0425
31	0.0077	0.0077	0.1437	0.0417	0.0531	0.0761
32	0.0084	0.0084	0.1372	0.0472	0.0625	0.0689
33	0.0063	0.0062	0.1353	0.0364	0.0460	0.0581
34	0.0077	0.0076	0.1418	0.0422	0.0541	0.0568
35	0.0075	0.0074	0.1425	0.0411	0.0522	0.0467
36	0.0069	0.0068	0.1455	0.0371	0.0460	0.0466
37	0.0074	0.0074	0.1467	0.0390	0.0496	0.0469
39	0.0056	0.0056	0.1437	0.0337	0.0381	0.0359
40	0.0084	0.0084	0.1525	0.0438	0.0556	0.0373
41	0.0071	0.0071	0.1502	0.0382	0.0479	0.0319
42	0.0058	0.0058	0.1463	0.0321	0.0386	0.0564
43	0.0079	0.0077	0.1495	0.0394	0.0503	0.0474
Total	0.0078	0.0077	0.1471	0.0414	0.0526	0.0559

Notes: 13-food processing; 14-food manufacturing; 15-beverage manufacturing; 17-textile; 18-garment, footwear and caps; 19-leather, fur, and feathers products; 20-timber and wood; 21-furniture; 22-paper products; 23-printing; 24-culture, education and sports articles; 25-petroleum and coking; 26-raw chemical materials; 28-chemical fibers; 29-rubber; 30-plastics; 31-nonmetallic products; 32-ferrous metals; 33-nonferrous metals; 34-metal products; 35-general machinery; 36-special machinery; 37-transport equipment; 39-electrical equipment; 40-communication equipment; 41-measuring instruments and machinery; 42-artwork and others; 43-recycle manufacturing. Road reliance rate is defined as the ratio of inputs related to transportation including truck transportation, transit and ground passenger transportation, scenic and sightseeing transportation and support activities, to the total input in each four-digit industry in the U.S.

3.3 Transport reliance rate

The transport reliance rate of an industry s is defined as the ratio of its inputs from transport-related industries to its total inputs. In particular,

$$tr_s = \frac{\text{Value of input from transport-related industries for industry} s}{\text{Total value of input for industry} s}$$

They download the input–output table from BEA in the version of NAICS 2007. Since there is no direct mapping between NAICS and CIC, they first translated NAICS to industry standard of ISIC (International Standard Industrial Classification) Rev 4, and then translated ISIC to CIC 2001.

3.2.4 Road length

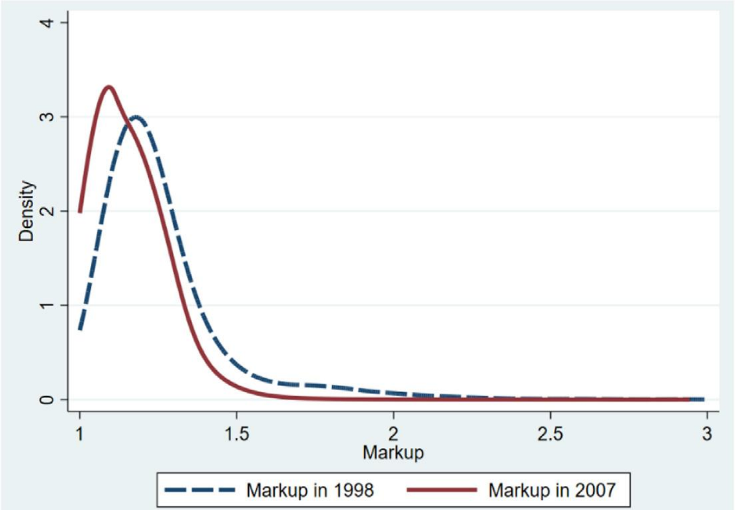
Road length is widely used as a proxy for total investment on road infrastructure.

This measure is especially applicable to developing economies, such as China, because their transport infrastructure investment focuses on new facilities rather than on maintenance (Li et al., 2017).

Hence, the road length of China's provinces should be highly correlated with their total investment on road infrastructure.

3.3. Performance of allocative efficiency in China

The distribution of firm markups to provide a rough picture of the allocative efficiency in China. Fig. 5 presents the kernel distribution of firm markups of Chinese manufacturing industries in 1998 and 2007.



Markup dispersion

They explicitly document markup dispersion by provincial road density (high versus low) and industrial transport reliance rate (high versus low) in 1998 and 2007

Panel B. Allocative efficiency within regions and industries

		Province road density (1998)			Industry road reliance		
		High	Low	Diff. (High vs. Low)	High	Low	Diff. (High vs. Low)
Markup dispersion (1998)	Theil	0.0231	0.0255	−0.002	0.0154	0.0144	0.001*
	MLD	0.0232	0.0255	−0.002	0.0150	0.0140	0.001*
	RMD	0.0833	0.0892	−0.006*	0.0660	0.0632	0.003**
	CV	0.2166	0.2282	−0.012	0.1793	0.1728	0.007*
	GINI	0.1194	0.1264	−0.007	0.0925	0.0896	0.003
Markup dispersion (2007)	Theil	0.0198	0.0221	−0.002	0.0130	0.0133	−0.000
	MLD	0.0201	0.0224	−0.002	0.0126	0.0129	−0.000
	RMD	0.0763	0.0826	−0.006	0.0609	0.0618	−0.001
	CV	0.1993	0.2103	−0.011	0.1636	0.1664	−0.003
	GINI	0.1101	0.1171	−0.007	0.0860	0.0870	−0.001
Diff. (1998 vs. 2007)	Theil	−0.0033*	−0.0034***		−0.0024***	−0.0011*	
	MLD	−0.0031*	−0.0030**		−0.0024***	−0.0011*	
	RMD	−0.0070	−0.0066**		−0.0051***	−0.0014	
	CV	−0.0173*	−0.0179***		−0.0157***	−0.0064*	
	GINI	−0.0094*	−0.0093*		−0.0065***	−0.0026	

Notes: TFP/markup dispersion is calculated for each province or industry at four-digit industry level in 1998 and 2007. For province road density, High refers to province road density higher than the median value and Low refers to province road density lower than the median value. For industry road reliance, High refers to a reliance rate higher than the median value and Low refers to a reliance rate lower than the median value.

4.1 Baseline regression specification

$$\mathrm{y}_{sjt} = \alpha_0 + \alpha_1 \mathrm{tr}_s * \mathrm{road}_{jt} + \sum_{t=99}^{07} \gamma_t X_{sj}^{98} * D_t + \mathrm{a}_{sj} + \mathrm{a}_{st} + \mathrm{a}_{jt} + \varepsilon_{sjt}$$

- y_{sjt}:markup dispersion in industry$s$, province j , and year t
- tr,:the transport reliance rate of industry s
- $\mathrm{road}_{\mathrm{jt}}$:the total road length (log) that reflects the road infrastructure in province and year t
- X_{sj}^{98}:the initial industry province characteristics in 1998 that may affect markup dispersion
- $\alpha_{si}, \alpha_{st}, \alpha_{jt}$:industry province, industry-year, and province-year fixed effects

4.2 Instrumental variable

- They construct a time-varying road length R$\widehat{\boldsymbol{oad}}_{jt}$
- Yearly road length should be jointly determined by the actual construction cost and the construction sequence
- Two components:regional variation at the province level and time variation across years
- $\widehat{Road}_j$:is calculated from the road route that policymakers and urban planners would have chosen if construction cost is the only determinant of roads
- $ratio_{jt}$: the budget ratio of road that should be built in each year t in each province j determined by the budget constraint on road investment in each year t and the priority of road construction among cities.

$$\widehat{Road}_{jt} = \widehat{Road}_j \times ratio_{jt}$$

5.1 Baseline estimation results

Table 4

Baseline estimation results of the effect of road infrastructure on markup dispersion.

Dependent variable: Markup dispersion	(1) OLS	(2) OLS	(3) IV	(4) IV
Road*reliance	−0.017	−0.022*	−0.326**	−0.474**
	(0.011)	(0.012)	(0.146)	(0.188)
Control variables	NO	YES	NO	YES
Industry-year FE	YES	YES	YES	YES
Province-year FE	YES	YES	YES	YES
Province-industry FE	YES	YES	YES	YES
Observations	74,392	63,712	74,392	63,712
Kleibergen-Paap rk Wald F	–	–	45.000	28.168

5.1 Baseline estimation results

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Kleibergen-Paap rk Wald F	–	–	45.000	28.168

-0.022

Semi-elasticity

one percentage increase of the road length would reduce the markup dispersion (Theil) by 0.00022 given that the transport reliance rate equals one.

5.1 Baseline estimation results

Table 3
Summary statistics of key variables.

Variables	Definition	Mean	Standard deviation
Dependent variables			
Theil	Theil index of markup in each four-digit industry-province-year	0.0078	0.0085
MLD	Mean log deviation of markup in each four-digit industry-province-year	0.0077	0.0085
CV	Coefficient of variation of markup in each four-digit industry-province-year	0.1471	0.0685
RMD	Relative mean deviation of markup in each four-digit industry-province-year	0.0414	0.0321
GINI	Gini coefficient in each four-digit industry-province-year	0.0526	0.0406
$Theil_{tfp}$	Theil index of TFP in each four-digit industry-province-year	0.0038	0.0091
$Theil_{profitmargin}$	Theil index of profit margin in each four-digit industry-province-year	0.2562	0.2345
HHI	Herfindahl-Hirschman index in each four-digit industry-province-year based on sales	0.5221	0.3436
Independent variables			
Road	Road length in log	10.8220	0.8242
Reliance	Transportation reliance rate in U.S.	0.0559	0.0188
Road* Reliance	Length of road of each province (log)* Transport reliance rate of each industry	0.6046	0.2095
Time sensitivity	Time sensitivity across industries in U.S.	0.0267	0.0128
Heaviness	Ratio of weight to value, and weights are measured in 10 tons in U.S.	0.0114	0.0234
Road* time sensitivity	Length of road of each province (log)* time sensitivity	0.2893	0.1412
Road* heaviness	Length of road of each province (log)*heaviness	0.1227	0.2531
Instrument variables			
IV for Road	Time-varying instrument measured by the predicted road length in log	2.5294	2.7491

5.2 Robustness checks

Table 5
Robustness Checks I: Long-difference estimation results of the effect of road infrastructure on markup dispersion.

Dependent variable: Markup dispersion	(1) OLS	(2) OLS	(3) IV	(4) IV
Road*reliance	−0.042	−0.047*	−0.364**	−0.372**
	(0.029)	(0.029)	(0.163)	(0.163)
Control variables	NO	YES	NO	YES
Industry FE	YES	YES	YES	YES
Province FE	YES	YES	YES	YES
Observations	4,313	4,313	4,313	4,313
Kleibergen-Paap rk Wald F	–	–	35.625	35.621

Table 6
Robustness Checks II: IV Estimation results using alternative indices of markup dispersion.

Dependent variable: Markup dispersion	(1) MLD	(2) CV	(3) RMD	(4) GINI
Road*reliance	−0.501***	−2.786*	-1.605**	−2.167***
	(0.188)	(1.488)	(0.633)	(0.783)
Control variables	YES	YES	YES	YES
Observations	63,712	51,447	63,712	63,712
Kleibergen-Paap rk Wald F	28.167	25.049	28.167	28.167

Table 7
Robust checks III: Moving average, lagged effect, shorter period, alternative markup measure, TFP dispersion, lobby activity and industrial characteristics.

Dependent variable	(1) Markup dispersion (Moving average)	(2) Markup dispersion	(3) Markup dispersion (2001–2004)	(4) Dispersion of Profit margin	(5) Dispersion of TFP	(6) Markup dispersion (Excl. Zhejiang)	(7) Markup dispersion	(8) Markup dispersion
Road*reliance	−0.479**		−0.560*	−12.639*	−0.172*	−0.500**		−0.551**
	(0.192)		(0.312)	(6.830)	(0.104)	(0.235)		(0.238)
Lagged road*reliance		−0.644***						
		(0.181)						
Road* heaviness							−0.194*	
							(0.110)	
Road*time sensitivity								0.178**
								(0.082)
Control variables	YES	YES	YES	YES	YES	YES	YES	YES
Observations	63,712	55,916	26,283	46,165	61,414	60,198	57,565	57,075
Kleibergen-Paap rk Wald F	28.168	26.398	82.457	18.931	43.110	17.155	25.778	22.402

6.1 Disentangling price effect and cost effect

Industry concentration degree

Road investment can decrease the concentration degree of an industry as reflected by the negative estimate of the interaction term.

Price dispersion and marginal cost dispersion

Both price and cost channels work to jointly shape the distribution of firm markups

Industry material input cost

Input prices matter in reducing markup dispersion through the cost channel.

Table 9
Effect of roads on industry concentration, dispersion of price and marginal cost, and interactive effect with material input.

Dependent variable	(1) HHI	(2) Price dispersion	(3) Marginal cost dispersion	(4) Markup dispersion
Road*reliance	-1.087	-12.148**	-12.079**	−0.369**
	(6.003)	(5.438)	(5.445)	(0.184)
Road*reliance*material				−0.052***
				(0.010)
Control variable	YES	YES	YES	YES
Observations	61,575	21,024	21,025	63,712
Kleibergen-Paap rk Wald F	23.133	56.742	56.743	14.513

6.1 Disentangling price effect and cost effect

Markup quantile regressions.

High-markup firms have relatively larger rooms than low-markup firms for reducing markups when facing fierce competition.

Isolating the price effect from markup.

Markup changes are largely due to price changes in product market

Table 10
Effects of roads on markups at different quantile levels.

Dependent variable: Markup	(1) 5%	(2) 25%	(3) 50%	(4) 75%	(5) 95%	(6) 5%	(7) 25%	(8) 50%	(9) 75%	(10) 95%
Road*reliance	3.864	1.220	−3.207	−5.998*	−11.619**	2.991	1.886	−2.454	−5.167**	−8.985*
	(3.251)	(2.851)	(2.834)	(3.638)	(5.206)	(2.684)	(2.225)	(2.272)	(2.964)	(5.409)
Marginal cost	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES
Control variables	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	62,079	62,079	62,079	62,079	62,079	23,246	23,246	23,246	23,246	23,246
Kleibergen-Paap rk Wald F	28.840	28.840	28.840	28.840	28.840	62.568	62.543	62.506	62.512	62.541

6.2. Manifestations of the pro-competitive effect of roads

Effect of road coverage

The procompetitive effect of roads is intensified in regions with denser road networks

Effect of firm density.

The pro-competitive effect of roads is strengthened when firms face more local competition

Effect of state ownership

SOEs are less sensitive to market competition comparing to their counterparts

Effect of business institutions.

The pro-competitive effect of road infrastructure is strengthened in provinces with better business institution quality.

Effect of road scope.

A stronger effect of local roads on reducing markup dispersions than national roads.

Conclusion

Conclusion 1

Road infrastructure improvement can significantly reduce firm markup dispersion, providing clear evidence of improved allocative efficiency and the presence of pro-competitive effect of transport infrastructure.

Conclusion 2

Support the belief that transport infrastructure investment plays a key role in promoting economic growth.

Conclusion 3

Their research emphasizes the allocative efficiency of resources within industries. Improving the institutional environment and promoting market competition are important to fully reap the efficiency gains of enhanced transport infrastructure

Easy Quiz for Exam

1. 当道路长度以对数形式计算时，回归系数-0.022 有何经济含义？(Semi-elasticity!)
2. 本表的第二列和第四列在回归方法上有何不同？

Table 4
Baseline estimation results of the effect of road infrastructure on markup dispersion.

Dependent variable: Markup dispersion	(1) OLS	(2) OLS	(3) IV	(4) IV
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Observations	74,392	63,712	74,392	63,712
Kleibergen-Paap rk Wald F	–	–	45.000	$\boxed{28.168}$

参考答案

1. 系数表示，假设运输依赖率为 1，道路长度增加 1% 将使加价离散度减少 0.00022
2. 第二列报告的是引入额外控制变量后，普通最小二乘法展示的回归结果; 第四列是采用时变道路长度的工具变量后计算的第二阶段回归结果.

Thank you for listening!