Estimating Productivity of Public Infrastructure Investment

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Motivation: China and Developing Economies

- Infrastructure investment is considered a precursor to economic development: "To get rich first build roads".
- The experience of China:
  - Infrastructure investment grows at 12.2% annually during 1998-2013.
  - Every year 9.7% of GDP has been spent on infrastructure investment.
  - 4 trillion RMB fiscal stimulus after the 2008 global financial crisis
  - 1 trillion RMB investment in infrastructure in 2015
  - 8 trillion USD infrastructure investment estimated for the OROB
- But do roads lead to prosperities or the other way round?
- And is such massive investment economically efficient and optimal?

Motivation: US and Developed Economies

- Most developed economies face the trade-off between economic growth and fiscal austerity in recent years.
- The European Debt Crisis makes fiscal austerity a golden discipline.
  - IMF: Urge dozens of countries to cut their government spending.
- The idea of using public investment to boost economic growth becomes even more appealing during economic downturns.
  - Trump's big infrastructure plan: $1 trillion infrastructure over 10 yeas
- But do big infrastructures promote economic growth?
- And is public investment really a free lunch?

Poll on Infrastructure Investment

- Conducted by Initiative on Global Markets Forum in Sept 2014
- 44 prominent economists from top US universities interviewed

- **Question A**: "Because the US has underspent on new projects, maintenance, or both, the federal government has an opportunity to **increase average incomes by spending more on roads, railways, bridges and airports**."
  - Vote: mostly Yes – 23% strong agree + 59% agree
  - Abhijit Banerjee: "Uncertain. Investment will probably raise incomes for Keynesian reasons **but will it promote growth**?"

Poll on Infrastructure Investment

- **Question B**: "Past experience of public spending and political economy suggests that if the government spent more on roads, railways, bridges and airports, many of the projects would have **low or negative returns**."
  - Vote: very mixed – from 5% strong agree to 16% disagree
  - Daron Acemoglu: "Uncertain. Past evidence suggests that there will be **waste and corruption** (a lot of corruption!). But this does not imply that average NPV is negative."
  - Abhijit Banerjee: "Agree. Many does not have to mean most, and on average returns may be quite positive. **We just don't know enough right now**. "

Research Questions

- What is average rate of return of public infrastructure investment?
  - Central to the current policy debates
  - Benchmark of the efficiency and optimality analyses
- Is it a short-run demand effect or long-run productivity effect?
  - Short-run: Keynesian demand effect of fiscal expansion?
  - Long-run: promoting growth by enhancing productivity?
- What are the mechanisms for such investment to be productive?
  - Vital to the evaluation of existing infrastructure projects
  - Vital to the planning of future infrastructure policies

Big Picture

- Theoretical literature
  - A big literature back to Barro (1990)
  - Studying government investment in an endogenous growth model
  - Resource-distorting tax trades off productivity-enhancing investment.
  - Conclusion: it is possible to have too much/little public investment.
- Empirical literature
  - Mainly focusing on cross-country/region time series/panel data
  - Using an public-capital-augmented aggregate production function
  - Estimating the average relation between public capital and GDP

Contrasting Empirical Findings

- A big literature back to Aschauer (1989)
  - Estimating output elasticity wrt public capital $= 0.38 \sim 0.56$
  - Implying rate of return $> 100\%$ in US during 1949-1985
- Estimated output elasticity varies widely in subsequent researches.
  - From lowest: -1.7 to highest: 2.04
  - Non-negligible share of estimates statistically not different from zero
- Two most recent studies
  - Warner (2014): little effect in developing economies
  - Shi and Huang (2014): very high return in China

Methodological Challenges in the Literature

- Reverse causality from output to public infrastructure
- Measurement errors in the stock of public capital
- Non-stationarity and common trend in macro data
- Simultaneity bias in production function estimation
- Demand effect versus productivity effect
- Interregional spillover effects
- Underlying mechanisms

This Paper

- Addresses a set of identification challenges in the literature with
  - a firm-level production function + an endogenous productivity
  - Chinese firm-level production data + province-level investment data
  - some additional structural assumptions on demand and spillover
- Estimated gross real rates of return during 1999-2007
  - 2.5% due to productivity effect
  - 9.2% due to productivity and demand effects
  - spillover effects triple the magnitudes
- Finds evidence consistent with a resource reallocation mechanism

Outline

- Introduction
- Baseline Model
- Extension
- Results
- Mechanism
- Conclusion

An Aggregate Production Function

- A two-factor model with Hicks-neutral productivity:

$$Q = AF(L, K)$$

- Public capital B contributes to total productivity factor A:

$$A = S(A_0, B)$$

- B evolves according to:

$$B_t = (1 - \delta_b)B_{t-1} + G_t$$

  - G: investment in public facilities with externalities;
  - δ_b: imposed depreciation rate of G.

- An augmented three-factor model:

$$Q = A_o F(B, L, K)$$

- Using C-D form and rewriting in logs:

$$\ln Q = \ln A_o + \alpha_b \ln B + \alpha_l \ln L + \alpha_k \ln K$$

Economic Rate of Return

- Differentiating the C-D production function:

$$\alpha_b = \frac{\partial \ln Q}{\partial \ln B} = \frac{\partial Q/Q}{\partial B/B} = \frac{\partial Q}{\partial B}\frac{B}{Q}$$

- Economic rate of return of public capital is defined as the marginal revenue product of public capital:

$$MRPB \equiv \frac{\partial Q}{\partial B} = \alpha_b \frac{Q}{B}$$

- Key parameter of interest:

α_b, output elasticity with respect to B

Main Challenge: Reverse Causality

- Consider how to estimate α_b in a panel data model:

$$\ln Q_{it} = \alpha_0 + \alpha_b \ln B_{it} + \alpha_l \ln L_{it} + \alpha_k \ln K_{it} + \mu_i + T_t + \varepsilon_{it} \quad (1)$$

- Eq. (1) aim to identify the causal effect of public capital on output.
- But the causality could go from output to public capital.
  - Higher Q_{it} means greater demand for amenities from B_{it}.
  - Higher Q_{it} means more revenue for expenditures on B_{it}.
- OLS estimates for α_b are most likely to be upward biased.

Dealing with Reverse Causality

- Instrumental variables approach
  - Hard to find convincing external IVs without the problem of weak IV
  - Internal IVs usually generate low returns (Holtz-Eakin, 1994)
- A simultaneous equations approach: Röller and Waverman (2001)
  - Modeling relationship between Q and B in an additional equation
  - Using the structure equation model to deal with the simultaneity
  - They have detailed price information, which is usually unavailable.
- Disaggregation: Fernald (1999)
  - Vehicle-intensive industries benefiting more from road-building
  - The logic is intuitive but hard to generalize to other infrastructure.

A Set of Other Challenges

- Consider how to estimate α_b in a panel data model:

$$\ln Q_{it} = \alpha_0 + \alpha_b \ln B_{it} + \alpha_l \ln L_{it} + \alpha_k \ln K_{it} + \mu_i + T_t + \varepsilon_{it} \quad (1)$$

- There are also a set of other challenges:
  - Constructing B requires history of G and assumed δ_b.
  - Macroeconomic variables are usually non-stationary.
  - Simultaneity bias arises due to correlation btw ε_{it} and (B_{it}, L_{it}, K_{it}).
  - The estimates may reflect both demand and productivity effect.
  - Sectorial or regional data may miss interregional spillover effects.
  - Homogeneous α_b leaves little possibility to investigate mechanisms.

A Firm-level Production Function

- Consider a firm i in industry s province j and active in year t.
- A Cobb-Douglas production function in log form:

$$r_{it} = \beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it} + \omega_{it} + \epsilon_{it} \tag{2}$$

  - r_{it}: real sales revenue
  - l_{it}, k_{it}, m_{it}: labor, capital and intermediate inputs
  - ω_{it}: unobservable firm-specific revenue-based productivity
  - ϵ_{it}: unobservable idiosyncratic shocks to sales revenue
- Eq. (2) is a specification widely used in the literature.

Endogenous Productivity

- Productivity ω_{it} follows a first-order Markov process:

$$\omega_{it} = h_t(\omega_{it-1}, g_{jt-1}) + v_{it} \quad (3)$$

  - g_{jt-1}: log of province j's public investment flow in year $t-1$
  - v_{it}: an unobservable firm-specific innovation to revenue productivity
  - It takes time for public investment to affect firm's productivity.
  - Contribution of previous public investment is absorbed by ω_{it-1}.
- Eq. (3) is inspired by two recent researches:
  - De Loecker (2013): productivity effect of trade
  - Doraszelki & Jaumandreu (2013): productivity effect of R&D

Unique Advantages of the TFPR Model

- We refer the system of equations (2) and (3) to the TFPR model:

$$r_{it} = \beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it} + \omega_{it} + \epsilon_{it} \quad (2)$$
$$\omega_{it} = h_t(\omega_{it-1}, g_{jt-1}) + v_{it} \quad (3)$$

- It avoids the reverse causality by nature.
  - Province-level g_{jt-1} is not/less affected by individual firm's r_{it};
  - Individual firm's r_{it} takes province-level g_{jt-1} as exogenously given.
- It avoids measurement errors in the stock of public capital.
  - Modelling ω_{it} as a function of g_{jt-1} and ω_{it-1}
  - Requiring data on investment flows rather than capital stock
- It avoids non-stationarity and common trend in data.
- It allows to control for simultaneity bias using the proxy method.

The Proxy Method

- To estimate productivity effect is to recover ω_{it} in (3).
- To recover ω_{it} is to estimate βs in production function (2).
- OLS estimates for βs are known for suffering from simultaneity bias.
- OP (1996), LP(2003) and ACF (2006) propose a proxy method.
- Assumption: m is a variable input and k is a dynamic input.
- Profit maximization implies optimal intermediate inputs:

$$m_{it} = m_t(l_{it}, k_{it}, \omega_{it})$$

- The strict monotonicity of m_{it} in ω_{it} implies an inverse function:

$$\omega_{it} = \omega_t(l_{it}, k_{it}, m_{it}) \tag{4}$$

First Stage Regression: getting rid of epsilon

- Denote

$$\beta \equiv (\beta_l, \beta_k, \beta_m)', \ x_{it} \equiv (l_{it}, k_{it}, m_{it})'$$

- Inserting eq. (4) into (2) yields a reduced-form equation:

$$r_{it} = x'_{it}\beta + \omega_{it} + \epsilon_{it} = \phi_t(x_{it}) + \epsilon_{it}$$

- where the proxy function $\phi_t(x_{it})$ is defined as

$$\phi_t(x_{it}) = x'_{it}\beta + \omega_t(x_{it})$$

- By construction ϵ_{it} has zero mean and is independent of x_{it}.
- Estimate $\phi_t(x_{it})$ by a nonparametric regression of r_{it} on x_{it}.
- This provides a fitted value $\hat{\phi}_t(x_{it})$ for r_{it}.
- Then ω_{it} is identified if β can be identified:

$$\omega_{it}(\beta) = \hat{\phi}_t(x_{it}) - x'_{it}\beta$$

Second Stage Estimation: identifying beta

- Running a nonparametric regression of ω_{it} on $\left(\omega_{it-1}, g_{jt-1}\right)$ to obtain the productivity innovation:

$$v_{it}(\beta) = \omega_{it}(\beta) - h_t(\omega_{it-1}(\beta), g_{jt-1})$$

- where for any given β, ω_{it} and ω_{it-1} are calculated as

$$\begin{aligned} \omega_{it}(\beta) &= \hat{\phi}_t(x_{it}) - x_{it}'\beta \\ \omega_{it-1}(\beta) &= \hat{\phi}_{t-1}(x_{it-1}) - x_{it-1}'\beta \end{aligned}$$

- If only k is a dynamic input, moment conditions for identifying β are:

$$E\left[(v_{it}(\beta_l, \beta_k, \beta_m)) \otimes \begin{pmatrix} l_{it-1} \\ k_{it} \\ m_{it-1} \end{pmatrix}\right] = 0$$

Economic Rate of Return

- Firm-specific output elasticity wrt public infrastructure investment:

$$e_{it} = \frac{\partial r_{it}}{\partial g_{jt-1}} = \frac{\partial \omega_{it}}{\partial g_{jt-1}} = \frac{\partial h_t}{\partial g_{jt-1}}$$

- Weighted-average industry-level output elasticity:

$$e_{st} = \left(\sum_i e_{it} \frac{R_{ist}}{R_{st}} \right) \frac{dv_s}{dr_s}$$

  - $\frac{R_{ist}}{R_{st}}$: firm i's revenue share; $\frac{dv_s}{dr_s}$: industry s's ratio btw v and r

- Weighted-average sector-level output elasticity:

$$e_t = \sum_s e_{st} \frac{V_{st}}{V_t}$$

  - $\frac{V_{st}}{V_t}$: industry s's value-added share

- Average rate of return to public investment:

$$MRPG_t = e_t \frac{GDP_t}{G_{t-1}}$$

Distinguish Production from Demand

- A Cobb-Douglas production function:

$$Q_{it} = L_{it}^{\alpha_L} K_{it}^{\alpha_K} M_{it}^{\alpha_M} \exp(\omega_{it}^q + \epsilon_{it}^q) \quad (5)$$

  - Q_{it}: firm i's physical output in year t
  - $\alpha_L, \alpha_K, \alpha_M$: output elasticities wrt L, K, M
  - ω_{it}^q: unobservable firm-specific quantity-based productivity
  - ϵ_{it}^q: unobservable idiosyncratic shocks to physical output

- A CES demand system similar to De Loecker (2011):

$$Q_{it} = Q_{sjt}(\frac{P_{it}}{P_{st}})^{-\sigma_s} \exp(\xi_{it}) \quad (6)$$

  - P_{it}: firm i's price in year t
  - P_{st}: an average price in industry s
  - Q_{sjt}: an aggregate demand shifter in industry s and province j
  - ξ_{it}: a firm-specific demand shifter
  - σ_s: elasticity of substitution for industry s, where $1 < \sigma_s < \infty$

The Effects of Public Infrastructure Investment

- To model the effect of infrastructure investment on production:

$$\omega_{it}^{q} = h_t^q(\omega_{it-1}^{q}, g_{jt-1}) + v_{it}^{q} \tag{7}$$

  - g_{jt-1}: log of province j's public investment flow in year $t-1$
  - v_{it}^{q}: an unobservable firm-specific innovation to quantity productivity
  - Infrastructure investment has a lagged effect on productivity.

- To model the effect of infrastructure investment on demand:

$$\xi_{it} = \tau g_{jt} + \widetilde{\xi}_{it}, \tag{8}$$

  - g_{jt}: log of province j's public investment flow in year t
  - $\widetilde{\xi}_{it}$: an unobservable firm-specific demand shock
  - Infrastructure investment has an instantaneous effect on demand.

Output and Price

- Rewrite eq (5) in log form:

$$\ln Q_{it} \equiv q_{it} = \alpha_l l_{it} + \alpha_k k_{it} + \alpha_m m_{it} + \omega_{it}^q + \epsilon_{it}^q \tag{9}$$

- Rewrite eq (6) in log form:

$$\ln P_{it} - \ln P_{st} = -\frac{1}{\sigma_s}\left(\ln Q_{it} - \ln Q_{sjt}\right) + \frac{1}{\sigma_s}\xi_{it} \tag{10}$$

- Physical output Q_{it} and firm-level price P_{it} are not observable.
- Common practice in the literature:
  - Sales revenue $P_{it}Q_{it}$ is taken as a proxy for output Q_{it}.
  - Firm-level sales revenue $P_{it}Q_{it}$ is deflated by an industry-wide producer price index P_{st}.

Log Real Sales Revenue

- Add $(\ln P_{it} - \ln P_{st})$ on both sides of eq (9):

$$\ln \frac{P_{it} Q_{it}}{P_{st}} = \alpha_l l_{it} + \alpha_k k_{it} + \alpha_m m_{it} + (\ln P_{it} - \ln P_{st}) + \omega_{it}^q + \epsilon_{it}^q$$

  - $\ln \frac{P_{it} Q_{it}}{P_{st}}$: log real sales revenue
  - $(\ln P_{it} - \ln P_{st})$: unobservable and negatively correlated with inputs
  - causing the omitted price variable bias in $\alpha_L, \alpha_K, \alpha_M$

- CES demand system allows us to replace $(\ln P_{it} - \ln P_{st})$ using (10):

$$\ln \frac{P_{it} Q_{it}}{P_{st}} = \left(1 - \frac{1}{\sigma_s}\right) \ln Q_{it} + \frac{1}{\sigma_s} \ln Q_{sjt} + \frac{1}{\sigma_s} \xi_{it} \qquad (11)$$

Estimation Equation

- Substitute $\ln Q_{it}$ and ξ_{it} in eq (11) using (9) and (8):

$$\ln \frac{P_{it} Q_{it}}{P_{st}} = \left(1 - \frac{1}{\sigma_s}\right)\left(\alpha_l l_{it} + \alpha_k k_{it} + \alpha_m m_{it}\right) + \left(1 - \frac{1}{\sigma_s}\right)\left(\omega_{it}^q + \epsilon_{it}^q\right) + \frac{1}{\sigma_s} \ln Q_{sjt} + \frac{1}{\sigma_s}\left(\tau g_{jt} + \widetilde{\xi}_{it}\right)$$

- Reparameterization leads to an estimation equation for revenue generating production function:

$$r_{it} = \beta_l^* l_{it} + \beta_k^* k_{it} + \beta_m^* m_{it} + \beta_s^* q_{sjt} + \beta_g^* g_{jt} + \omega_{it}^* + \epsilon_{it}^* \qquad (12)$$

  - $r_{it} = \ln \frac{P_{it} Q_{it}}{P_{st}}$; $q_{sjt} = \ln Q_{sjt}$
  - $\beta_h^* = \left(1 - \frac{1}{\sigma_s}\right)\alpha_h$ for $h = \{l, m, k\}$; $\beta_s^* = \frac{1}{\sigma_s}$; $\beta_g^* = \frac{\tau}{\sigma_s}$
  - $\omega_{it}^* = \left(1 - \frac{1}{\sigma_s}\right)\omega_{it}^q = \left(1 - \beta_s^*\right)\omega_{it}^q$
  - $\epsilon_{it}^* = \left(1 - \frac{1}{\sigma_s}\right)\epsilon_{it}^q + \frac{1}{\sigma_s}\widetilde{\xi}_{it} = \left(1 - \beta_s^*\right)\epsilon_{it}^q + \beta_s^* \widetilde{\xi}_{it}$

TFPQ Model vs TFPR Model

- We refer the system of equations (12) and (7) to the TFPQ model:

$$r_{it} = \beta_l^* l_{it} + \beta_k^* k_{it} + \beta_m^* m_{it} + \beta_s^* q_{sjt} + \beta_g^* g_{jt} + \omega_{it}^* + \epsilon_{it}^* \quad (12)$$

$$\omega_{it}^q = h_t^q(\omega_{it-1}^q, g_{jt-1}) + v_{it}^q \quad (7)$$

- In contrast to the TFPR model:

$$r_{it} = \beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it} + \omega_{it} + \epsilon_{it} \quad (2)$$

$$\omega_{it} = h_t(\omega_{it-1}, g_{jt-1}) + v_{it} \quad (3)$$

- Eq (12) includes q_{sjt} and g_{jt} to control for the demand effects.
- The ω_{it}^q in eq (7) is known as the quantity total factor productivity.
- The ω_{it} in eq (2) also absorbs the demand shocks on the sales revenue and is thus known as the revenue total factor productivity.

Output Elasticity in the TFPQ Model

- Consider productivity effect of infrastructure investment as in eq (9):

$$\ln Q_{it} = \alpha_l l_{it} + \alpha_k k_{it} + \alpha_m m_{it} + \omega^q_{it} + \epsilon^q_{it} \tag{9}$$

- Our key parameter of interest is the phyical output elasticity:

$$e^q_{it} = \frac{\partial \ln Q_{it}}{\partial g_{jt-1}} = \frac{\partial \omega^q_{it}}{\partial g_{jt-1}}$$

- Eq (9) is not estimable but eq (12) is:

$$r_{it} = \beta^*_l l_{it} + \beta^*_k k_{it} + \beta^*_m m_{it} + \beta^*_s q_{sjt} + \beta^*_g g_{jt} + \omega^*_{it} + \epsilon^*_{it} \tag{12}$$

- The relationship between ω^q_{it} and ω^*_{it} implies that:

$$e^q_{it} = \frac{\partial \omega^q_{it}}{\partial g_{jt-1}} = \frac{1}{(1-\beta^*_s)} \frac{\partial \omega^*_{it}}{\partial g_{jt-1}}$$

- We use e^q_{it} to calculate the rate of return based on TFPQ model.

Rationale for Spillover Effects

- Firm i's productivity may benefit not only from public investment in its location j, but also from those in the rest of the country.
- Firm i's demand may be shifted not only by public investment in its location j, but also by those in the rest of the country.
- An argument used to explain a typical finding in the literature:

$$\alpha_B \text{ (aggregated data)} > \alpha_B \text{ (disaggregated data)}$$

- Some strategies in the literature:
  - Holtz-Eakin and Schwartz (1995): "effective" public infrastructure = neighboring regions + region itself
  - Pereira and Roca-Sagales (2003): aggregate effects of public infrastructure = direct effects + spillover effects

Specifications for Spillover Effects

- Revise the productivity equation in the TFPR model as:

$$\omega_{it} = h_t(\omega_{it-1}, \overline{g}_{jt-1}) + v_{it}$$

- Revise the productivity equation in the TFPQ model as:

$$\omega^q_{it} = h^q_t(\omega^q_{it-1}, \overline{g}_{jt-1}) + v^q_{it}$$

- Revise the CES demand system in the TFPQ model as:

$$Q_{it} = \overline{Q}_{sjt}(\frac{P_{it}}{P_{st}})^{-\sigma_s} \exp(\xi_{it})$$

- Revise the demand shifter equation in the TFPQ model as:

$$\xi_{it} = \tau\overline{g}_{jt} + \widetilde{\xi}_{it}$$

Weighting Matrix

- $\overline{G}_{jt}$ is the weighted-average of G_{kt}:

$$\overline{G}_{jt} = \sum w_{jk} * G_{kt}$$

- $\overline{Q}_{sjt}$ is the weighted-average of Q_{skt}:

$$\overline{Q}_{sjt} = \sum w_{jk} * Q_{skt}$$

- The weighting matrix w_{jk} is constructed as in Ertur & Koch (2007):

$$\begin{aligned} w_{jk} &= \frac{\frac{1}{d_{jk}}}{\sum_{k!=j} \frac{1}{d_{jk}}} \text{ for } k! = j \\ w_{jj} &= 1 \end{aligned}$$

- where d_{jk} is the physical distance between capital cities of provinces j and k measured from Google map.

Firm-level Data

- China's Industrial Survey over 1998-2007
    - All SOEs and non-SOEs with sales revenue above 5 million RMB
    - Producing 80% value-added of the industrial sector
    - Collected by National Bureau of Statistics of China annually
    - Firm productivity varies across industries and years.
- Dealing with the data: following Brandt et al. (2013)
    - Focusing on the 29 industries in the manufacturing sector
    - Constructing a panel using unique firm IDs
    - Estimating capital stock by perpetuity inventory method
    - Deflating output and input using industry-wide price indices
- See Table 1 for industry, observations and productivity growth.

Table 1 Firm-level data description

industry	definition	(1)	(2)	(3)	(4)
13	Food processing	13,029	6.9	11.2	126.72
14	Food manufacturing	5,246	6.7	10.6	106.94
15	Beverage manufacturing	3,590	8.2	11.1	102.26
16	Tobacco processing	264	6.4	9.0	121.75
17	Textile industry	17,562	7.0	12.0	109.13
18	Garments & other fiber products	9,725	5.6	9.9	103.03
19	Leather, furs, down & related products	4,861	6.7	9.8	109.42
20	Timber processing, bamboo, cane, palm fiber	4,453	11.0	15.3	108.26
21	Furniture manufacturing	2,365	7.2	11.1	104.87
22	Papermaking & paper products	6,124	7.4	10.7	105.03
23	Printing industry	4,361	4.5	7.1	93.40
24	Cultural, educational & sports goods	2,658	4.8	9.8	107.00
25	*Petroleum processing & coking*	*1,802*	*1.6*	*8.5*	*201.03*
26	Raw chemical materials & chemical products	14,970	7.5	12.1	122.16
27	Medical & pharmaceutical products	4,303	8.4	13.1	96.49
28	Chemical fiber	1,031	6.6	9.2	122.58
29	Rubber products	2,427	7.3	10.4	111.31
30	Plastic products	9,446	5.4	8.6	114.49
31	Nonmetal mineral products	17,594	10.3	13.2	106.08
32	Smelting & pressing of ferrous metals	4,948	8.8	15.3	133.74
33	*Smelting & pressing of nonferrous metals*	*3,643*	*1.8*	*6.1*	*196.66*
34	Metal products	11,018	6.1	10.8	114.41
35	Ordinary machinery	15,358	8.7	13.7	105.55
36	Special purpose equipment	8,606	7.2	12.4	106.39
37	Transport equipment	9,896	7.4	12.3	96.11
39	Electric equipment & machinery	12,025	4.7	9.9	117.62
40	Electronic & telecommunications equipment	6,766	7.5	11.9	83.49
41	Instruments, meters, cultural & office equipment	2,907	6.3	11.0	92.19
42	Other manufacturing	3,952	2.4	8.5	117.17
	average	7,067	6.6	10.8	115.01

Note:

(1): # of observations per year: (number of total firms for each industry during 1998-2007)/10

(2): labor productivity growth (%): median real growth rate of value-added/employees

(3): capital productivity growth (%): median real growth rate of value-added/capital stock

(4): output deflator of 2007 (1998 = 100): from Brandt et al. (2012)

Province-level Infrastructure Investment Data

- Data source: China Fixed Asset Investment statistics Yearbook
- Infrastructures investment includes investment to
  - (1) production and supply of electricity, gas and water
  - (2) transport, storage and post
  - (3) information transmission, computer services and software
  - (4) management of water conservancy, environment, and public facilities
- Define (1) + (2) + (3) as core infrastructure – benchmark
- Define core + (4) as broad infrastructure – robustness check
- See Table 2 for data on core and broad infrastructure investment.

Table 2 Data description on infrastructure investment

	average	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
core infrastructure investment											
volume (billion Yuan, 1998 price)	1184.1	729.4	778.0	845.9	884.6	891.9	1058.9	1284.6	1559.1	1847.6	1961.5
real growth rate (%)	11.9	NA	6.7	8.7	4.6	0.8	18.7	21.3	21.4	18.5	6.2
investment/industrial GDP (%)	21.2	21.5	21.1	20.9	20.1	18.5	19.4	21.1	23.0	24.2	22.3
investment/total GDP (%)	8.9	8.6	8.5	8.5	8.2	7.6	8.2	9.1	9.9	10.4	9.7
broad infrastructure investment											
volume (billion Yuan, 1998 price)	1619.5	929.1	1022.4	1120.5	1194.5	1272.8	1472.2	1734.5	2106.5	2545.0	2797.9
real growth rate (%)	13.2	NA	10.0	9.6	6.6	6.6	15.7	17.8	21.4	20.8	9.9
investment/industrial GDP (%)	28.8	27.4	27.8	27.7	27.2	26.3	27.0	28.6	31.1	33.3	31.8
investment/total GDP (%)	12.1	10.9	11.2	11.3	11.1	10.9	11.4	12.2	13.3	14.3	13.8

Note:

1. Data are from China Statistics Yearbooks and China Fixed Investment Statistical Yearbooks.
2. Infrastructure investment data are deflated by the price indices of investment in fixed assets by province.
3. Industrial GDP and total GDP data are deflated by the corresponding GDP deflators.
4. For the definitions of core and broad infrastructure investment, see Section 3.1.2.

Estimating the Productivity Process: the TFPR Model

- We use a fourth-order polynomial to estimate eq (3):

$$\omega_{it} = h_t(\omega_{it-1}, g_{jt-1}) + v_{it} \tag{3}$$

- See Table 3 for the estimates of endogenous productivity process.
- Findings:
  - The productivity process is highly non-linear.
  - Both g_{jt-1} and $\omega_{it-1} \cdot g_{jt-1}$ are highly significant.
  - Elasticity $e_{it} = \partial\omega_{it}/\partial g_{jt-1} = 0.023$ at median ω_{it-1}.
- Implications:
  - On average g_{jt-1} has a positive effect on ω_{it}.
  - The effect of g_{jt-1} on ω_{it} is firm-specific.
  - The effect depends on a firm's attained productivity level ω_{it-1}.

Table 3 Productivity process: TFPR model

Depedent variable: $\omega_{i,t}$

	Estimate	Standard error
$\omega_{i,t-1}$	-0.809 ***	0.017
$\omega^2_{i,t-1}$	-0.022 ***	0.002
$\omega^3_{i,t-1}$	0.000 ***	0.001
$\omega^4_{i,t-1}$	0.000 ***	0.000
$g_{j,t-1}$	-0.027 ***	0.001
$\omega_{i,t-1} * g_{j,t-1}$	0.088 ***	0.001
$e_{it} = \partial\omega_{i,t} / \partial g_{j,t-1}$ at median $\omega_{i,t-1}$:		0.023
# of observations:		1,347,547
R-squared:		0.770

Note:

1. Industrial dummies are included.

2. *** p<0.01, ** p<0.05, * p<0.1

Estimating the Output Elasticities: the TFPR Model

- To highlight the heterogeneity, we also calculate the elasticities
  - by industry
  - at the 25^{th}, 50^{th} and 75^{th} percentiles of the lagged productivity
- See Table 4 for output elasticities by industry and by productivity.
- Findings:
  - Substantial variations along productivity distribution within industry
  - For all industries the effects increase with the initial productivity level
  - Firms at higher quantiles of productivity usually benefit
  - Firms at lower quantiles of productivity gain less or even lose

Table 4 Output elasticities by productivity percentile: TFPR model

industry	25th percentile	50th percentile	75th percentile
13	-0.003	-0.002	0.000
14	0.021	0.021	0.021
15	-0.001	0.004	0.008
16	0.033	0.035	0.039
17	-0.001	0.005	0.014
18	0.026	0.026	0.027
19	0.002	0.006	0.014
20	-0.011	0.004	0.020
21	-0.015	0.000	0.020
22	0.013	0.016	0.020
23	0.040	0.043	0.046
24	0.012	0.021	0.030
26	0.001	0.002	0.003
27	0.017	0.024	0.033
28	0.005	0.015	0.024
29	-0.023	0.005	0.015
30	-0.003	0.001	0.002
31	0.014	0.021	0.028
32	-0.006	-0.004	-0.002
34	-0.015	-0.008	-0.002
35	0.009	0.018	0.022
36	0.003	0.009	0.013
37	0.002	0.008	0.013
39	-0.027	-0.025	-0.024
40	0.020	0.020	0.020
41	-0.024	-0.008	0.017
42	-0.001	0.001	0.003
average	0.003	0.009	0.016

Note:

This table reports the output elasticities at the 25th, 50th and 75th percentiles of $\omega_{i,t-1}$.

Estimating the Rates of Return: the TFPR Model

- We calculate the rates of return by
  - aggregating firm-level output elasticities to industry-average
  - aggregating industry-level output elasticities to sector-average
  - adjusting the elasticity with the corresponding GDP/G ratio
- See Table 5 for output elasticities and average rates of return.
- Findings:
  - The 9-year average rate of return during 1999-2007 is 9.2%.
  - Yearly returns bottom at 8.0% in 1999 and peak to 10.7% in 2003.

Table 5 Output elasticities and average rates of return: TFPR model

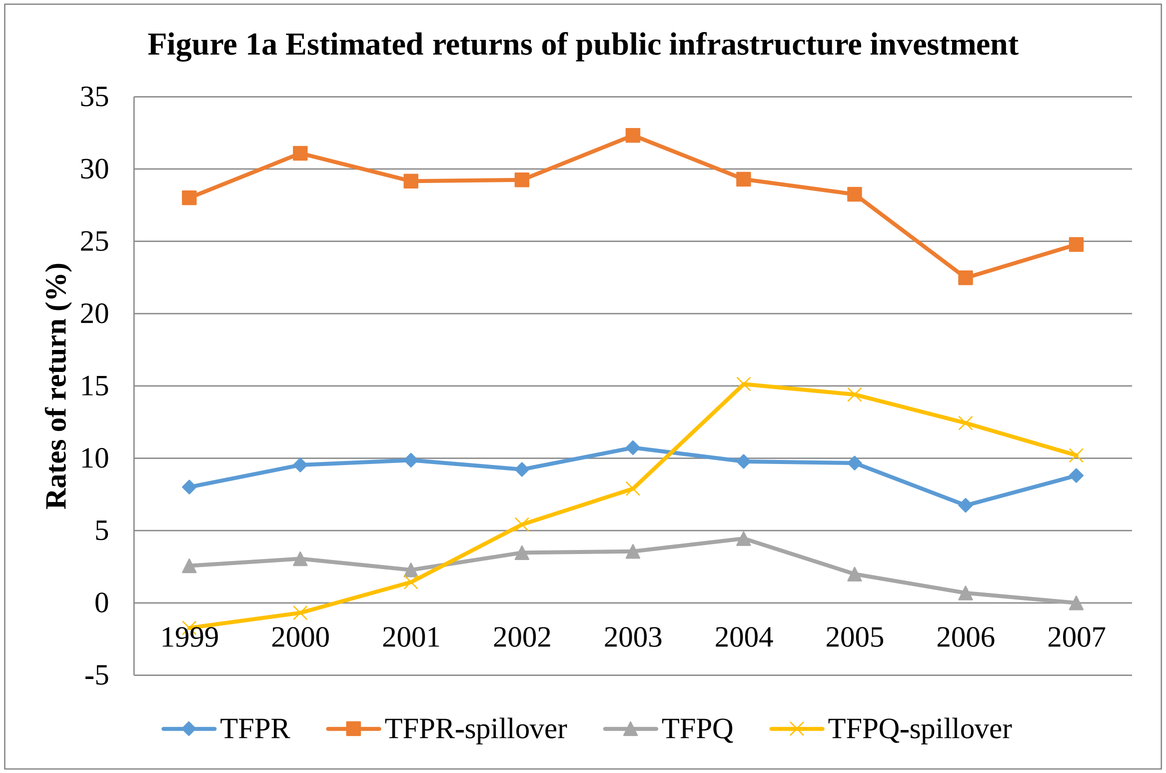
industry	9-year average	1999	2000	2001	2002	2003	2004	2005	2006	2007
13	-0.002	0.000	0.000	-0.001	-0.001	-0.002	-0.003	-0.003	-0.004	-0.004
14	0.017	0.018	0.018	0.018	0.017	0.018	0.017	0.016	0.017	0.017
15	0.005	0.000	0.002	0.004	0.004	0.007	0.004	0.006	0.007	0.010
16	0.025	0.024	0.025	0.024	0.024	0.024	0.025	0.026	0.026	0.025
17	0.007	0.016	0.013	0.013	0.012	0.010	0.007	0.005	-0.020	0.005
18	0.022	0.023	0.023	0.022	0.022	0.022	0.022	0.021	0.021	0.021
19	0.009	0.014	0.016	0.013	0.013	0.012	0.007	0.004	0.002	0.002
20	0.014	0.035	0.030	0.020	0.022	0.022	0.014	0.005	-0.005	-0.011
21	0.009	0.022	0.023	0.019	0.018	0.016	0.010	0.002	-0.011	-0.017
22	0.016	0.011	0.012	0.013	0.013	0.014	0.015	0.018	0.021	0.022
23	0.036	0.034	0.034	0.035	0.035	0.035	0.036	0.037	0.038	0.039
24	0.019	0.026	0.027	0.024	0.025	0.024	0.020	0.012	0.008	0.006
26	0.001	0.003	0.002	0.002	0.002	0.002	0.001	0.001	0.000	0.000
27	0.026	0.020	0.019	0.022	0.022	0.024	0.025	0.032	0.034	0.038
28	0.014	0.011	0.023	0.018	0.017	0.005	0.022	0.024	0.012	-0.006
29	-0.004	-0.021	-0.020	-0.015	-0.014	-0.011	0.002	0.012	0.017	0.018
30	0.000	-0.003	-0.003	-0.002	-0.002	-0.002	0.000	0.002	0.002	0.003
31	0.016	0.011	0.010	0.012	0.012	0.012	0.015	0.020	0.023	0.026
32	-0.002	-0.006	-0.005	0.007	0.003	0.006	0.000	-0.011	-0.010	-0.004
34	-0.002	0.004	0.005	0.001	0.001	0.000	-0.004	-0.008	-0.008	-0.010
35	0.016	0.004	0.017	0.014	0.008	0.014	0.018	0.020	0.017	0.028
36	0.007	0.003	0.003	0.004	0.004	0.005	0.006	0.010	0.012	0.013
37	0.004	-0.001	0.000	0.001	0.001	0.002	0.004	0.008	0.010	0.012
39	-0.024	-0.027	-0.025	-0.027	-0.028	-0.027	-0.026	-0.011	-0.018	-0.028
40	0.018	0.017	0.017	0.018	0.018	0.018	0.018	0.018	0.018	0.018
41	0.002	0.027	0.023	0.017	0.011	0.005	-0.003	-0.013	-0.024	-0.028
42	0.001	-0.002	-0.001	0.000	0.000	0.001	0.002	0.003	0.003	0.004
sector average elasticity	0.007	0.006	0.007	0.008	0.007	0.007	0.007	0.008	0.006	0.008
industrial GDP/G	5.298	5.048	5.196	5.193	5.461	6.107	5.736	5.276	4.906	4.757
total GDP/G	12.630	12.525	12.733	12.682	13.229	14.437	13.385	12.285	11.406	10.992
return to industry (%)	3.8	3.2	3.9	4.0	3.8	4.5	4.2	4.2	2.9	3.8
return to economy (%)	9.2	8.0	9.5	9.9	9.2	10.7	9.8	9.7	6.7	8.8

Note:

1. The numbers in the upper panel are the industry weighted average elasticities and their 9-year averages.
2. Sector average elasticity denotes the weighted average elasticity of the manufacturing sector.
3. Return to industry is the product of sector average elasticity and industrial GDP/G.
4. Return to economy is the product of sector average elasticity and total GDP/G.

Rates of Return in Alternative Models

- We estimate alternative models and calculate the rates of return.
- See Figure 1a for the summary of returns.
- The 9-year average rates of return are:
  - 9.2% from the TFPR model
  - 2.5% from the TFPQ model
  - 28.3% from the TFPR model with spillover effects
  - 7.2% from the TFPQ model with spillover effects
- Implications:
  - 2/3 of the positive effects are due to the Keynesian demand effect.
  - Spillover effects are substantial for large economies such as China.



Note:

This figure reports the returns of public infrastructure investment over 1999-2007 in 4 models: TFPR, TFPR with spillover effects, TFPQ and TFPQ with spillover effects, respectively.

Robustness Checks

- See Table 13 for estimated returns from robustness checks.
- Experimenting different polynomials to approximate $\phi_t(\cdot)$ and $h_t(\cdot)$
    - different returns from linear and quadratic specifications
    - similar and stable returns from 3^{rd} order and onwards
- Using broad instead of core infrastructure public investment
    - still positive returns as expected
    - smaller than returns for core infrastructure as expected
- Modelling spillover effects only from neighboring provinces
    - larger than returns without spillover effects as expected
    - smaller than returns with national spillover effects as expected

Table 13 Robustness checks

Panel a) Broad infrastructure investment

	9-year average	1999	2000	2001	2002	2003	2004	2005	2006	2007
					TFPR model					
sector average elasticity	0.008	0.007	0.008	0.009	0.008	0.008	0.008	0.009	0.008	0.009
total GDP/BG	9.351	9.832	9.689	9.574	9.798	10.116	9.627	9.098	8.442	7.980
return to economy (%)	7.8	7.1	8.2	8.3	7.7	8.5	8.1	8.4	6.4	7.5
					TFPQ model					
sector average elasticity	0.001	0.000	0.000	0.000	0.001	0.001	0.003	0.002	0.001	0.000
total GDP/BG	9.351	9.832	9.689	9.574	9.798	10.116	9.627	9.098	8.442	7.980
return to economy (%)	0.9	-0.2	0.3	0.1	1.2	1.4	2.7	1.5	0.7	0.1

Panel b) Third-order polynomials

	9-year average	1999	2000	2001	2002	2003	2004	2005	2006	2007
					TFPR model					
sector average elasticity	0.005	0.004	0.004	0.005	0.005	0.004	0.005	0.006	0.007	0.007
total GDP/G	12.630	12.525	12.733	12.682	13.229	14.437	13.385	12.285	11.406	10.992
return to economy (%)	6.5	5.1	5.7	5.8	6.2	6.4	7.0	8.0	7.5	7.1
					TFPQ model					
sector average elasticity	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.002	0.001
total GDP/G	12.630	12.525	12.733	12.682	13.229	14.437	13.385	12.285	11.406	10.992
return to economy (%)	3.0	2.2	2.9	2.6	3.9	4.4	4.5	3.7	2.0	0.9

Panel c) Spillover effects from neighbouring provinces

	9-year average	1999	2000	2001	2002	2003	2004	2005	2006	2007
					TFPR model					
sector average elasticity	0.015	0.015	0.017	0.015	0.014	0.014	0.014	0.015	0.012	0.016
total GDP/G	12.630	12.525	12.733	12.682	13.229	14.437	13.385	12.285	11.406	10.992
return to economy (%)	18.6	19.2	21.3	18.6	19.1	20.7	18.9	18.2	13.8	17.6
					TFPQ model					
sector average elasticity	0.002	-0.004	-0.002	-0.001	0.001	0.002	0.006	0.006	0.006	0.007
total GDP/G	12.630	12.525	12.733	12.682	13.229	14.437	13.385	12.285	11.406	10.992
return to economy (%)	3.0	-4.5	-2.8	-1.6	1.6	3.4	8.2	7.1	7.3	8.0

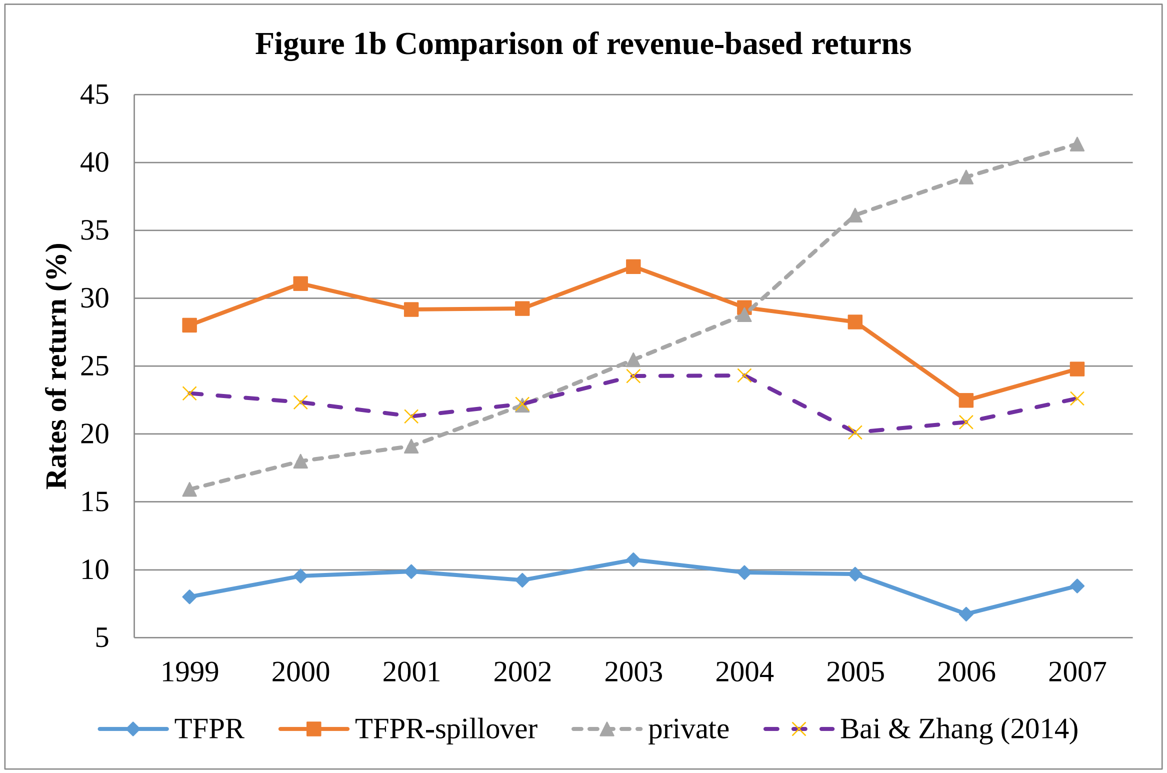
Note:

1. Sector average elasticity denotes the weighted average elasticity of the manufacturing sector.

2. Return to economy is the product of sector average elasticity and GDP/BG in panel a) (and GDP/G in panels b) and c)).

An Evaluation on the Rates of Return

- Our estimated average rates of return are:
  - 28.3% and 9.2% from TFPR model with/without spillover
  - 7.2% and 2.5% from TFPQ model with/without spillover
- Congressional Budget Office of the US:
  - a return of 15%-35% for urban highway in early 1980s
- Ministry of Housing and Urban-Rural Development of China:
  - using an 8% discount rate in feasibility study before implementation
- Estimated returns to private investment from same model and data:
  - an average of 27.3% return for the manufacturing sector
- Estimated returns to physical investment in Bai and Zhang (2014):
  - an average of 22.3% return for the whole economy
- See Figure 1b for comparison of revenue-based returns.



Note:

This figure compares the returns of public infrastructure investment in two models: TFPR, TFPR with spillover effects, with our estimated returns of private capital and the returns of physical investment from Bai and Zhang (2014).

Possible Channels in the Literature

- Possible channels for a positive effect
  - Economy of scale in production (Aschauer, 1989)
  - Reduction in transaction costs (Yang and Ng, 1993)
  - Reduction in transportation costs (Fernald, 1999)
  - Spatial spillover (Holtz-Eakin and Schwartz, 1995)
  - Network externalities (Röller and Waverman, 2001)
- Possible channels for a negative effect
  - Tax distortion in financing public investment (Barro, 1990)
  - Crowding-out effect on private investment (Cavallo and Daude, 2011)
  - Inefficiency and corruption (Keefer and Knack, 2007)

More Recent Findings

- Public infrastructure impacts the distribution of economic activities.
- Banerjee et al. (2012): proximity to transportation networks
  - has a moderately positive causal effect on per capital GDP levels
  - has no effect on per capital GDP growth
- Faber (2014): National Trunk Highway System
  - can lead to a reduction in industrial and total output growth
  - among connected peripheral counties relative to non-connected ones
- Baum-Snow et al. (2015): roads and railways
  - can lead to decentralization of Chinese cities
  - in terms of population and industrial GDP.
- All these researches use county-level or city-level data.

Facts on the Effects of Public Infrastructure

- Our findings on the effects of public infrastructure investment
  - Positive at aggregate level and heterogeneous at firm-level
  - Across firms the effects increase with attained productivity level.
- But productivity itself is not directly observable.
- See Table 10 for regression of elasticities over observables.
- Finding:
  - larger elasticities for young, small, non-SOE, exporting, Eastern firms
  - A robust pattern across all models with different specifications
- Implication:
  - More productive firms benefit more from public infrastructure

Table 10 Linking output elasticity with firm characteristics

Dependant variable: output elasticity*1000

model	TFPR	TFPQ	TFPR-spillover	TFPQ-spillover
age	-0.002***	-0.002***	-0.002***	-0.002***
	(0.000)	(0.000)	(0.000)	(0.001)
lnemp	-0.090***	-0.190***	-0.202***	-0.221***
	(0.019)	(0.014)	(0.041)	(0.032)
NSOE	1.223***	1.657***	0.605***	0.665***
	(0.078)	(0.057)	(0.160)	(0.128)
EXPORT	0.725***	0.476***	0.668***	1.572***
	(0.027)	(0.027)	(0.049)	(0.059)
EASTERN	0.480***	1.968***	0.163***	0.876***
	(0.029)	(0.028)	(0.063)	(0.060)
observations	1,346,897	1,346,897	1,346,897	1,346,897
R-squared	0.49	0.774	0.48	0.774

Note:

1. age: firm's age
2. lnemp: log of number of employees
3. NSOE: non-SOE dummy, non-SOEs = 1, SOEs = 0
4. EXPORT: exporter dummy, exporters = 1, nonexporters = 0
5. EASTERN: location dummy, eastern provinces = 1, noneastern provinces = 0
6. Industry dummies and year dummies are included in all regressions.
7. Robust standard errors are reported in parentheses.
8. *** p<0.01, ** p<0.05, * p<0.1

Resource Reallocation via Trade

- Hypothesis: public infrastructure investment facilitates resource reallocation via the channel of trade.
- Public infrastructure investment promotes a trade liberalization:
  - an increase in the number of trading partners
  - a decrease in the variable trade cost
  - a decrease in the fixed market entry cost
- Melitz (2003): a trade liberalization will
  - in a dynamic industry with hetergenous firms
  - force the least productive firms to exit;
  - reallocate market shares from less to more productive firms;
  - Both the intensive and extensive margins increase aggregate productivity by resource reallocation.
- Tombe and Zhu (2015) find that reductions in international and in particular internal trade costs account for two-fifths of aggregate productivity growth in China between 2000 and 2005.

Testing the Hypothesis

- We examine two specific predictions derived from Melitz (2003).
- First, all else being equal, public infrastructure investment increases the probability of exit of the less productive firms.
- Second, all else being equal, public infrastructure investment increases the market shares of the more productive firms.

The Exit Model

- See Table 11 for the Probit regressions of exit probability.
- Findings:
    - Productivity and capital stock have expected signs.
    - Overall infrastructure investment itself reduces the probability of exit.
    - The impact of infrastructure investment on a firm's exit probability depends on the firm's productivity.
    - A low productivity firm is indeed more likely to exit with more infrastructure investment.
    - A robust pattern across all models with different specifications

Table 11 Probit regressions of exit probability

Dependent variable: firm *i* 's exit in year *t* +1

model	TFPR			TFPR-spillover		
	(1)	(2)	(3)	(1)	(2)	(3)
Productivity	-0.142***	-0.140***	-0.0958***	-0.143***	-0.140***	-0.091***
	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)	(0.005)
Capital	-0.137***	-0.136***	-0.138***	-0.136***	-0.136***	-0.137***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Infrastructure		-0.088***	-0.091***		-0.172***	-0.178***
		(0.003)	(0.003)		(0.006)	(0.006)
Infrastructure*Low			0.005***			0.005***
			(0.000)			(0.000)
# of obs.	1,106,116	1,106,116	1,106,116	1,106,116	1,106,116	1,106,116
predicted prob	0.112	0.112	0.111	0.112	0.112	0.111

model	TFPQ			TFPQ-spillover		
	(1)	(2)	(3)	(1)	(2)	(3)
Productivity	-0.148***	-0.159***	-0.112***	-0.141***	-0.151***	-0.104***
	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)	(0.005)
Capital	-0.136***	-0.135***	-0.136***	-0.136***	-0.135***	-0.135***
	(0.001)	(0.001)	-(0.001)	(0.001)	(0.001)	(0.001)
Infrastructure		-0.106***	-0.120***		-0.205***	-0.233***
		(0.003)	(0.003)		(0.006)	(0.006)
Infrastructure*Low			0.005***			0.005***
			(0.000)			(0.000)
# of obs.	1,106,116	1,106,116	1,106,116	1,106,116	1,106,116	1,106,116
predicted prob	0.112	0.111	0.111	0.112	0.111	0.111

Note:

1. Industry dummies and year dummies are included in all regressions.
2. LOW: dummy variable, LOW_{it} = 1 (0) if productivity is below (beyond) median.
3. *** p<0.01, ** p<0.05, * p<0.1

The Market Share Model

- See Table 12 for the regressions of market share.
- Findings:
  - Productivity and capital stock have expected signs.
  - Overall infrastructure investment itself contributes to market share.
  - The impact of infrastructure investment on a firm's market share depends on the firm's productivity.
  - A high productivity firm is indeed more likely to gain market share with more infrastructure investment.
  - A robust pattern across all models with different specifications

Table 12 Regressions of market share

Dependent variable: firm *i* 's market share in year *t*

model	TFPR			TFPR-spillover		
	(1)	(2)	(3)	(1)	(2)	(3)
Productivity	0.532***	0.534***	0.380***	0.517***	0.520***	0.363***
	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)
Capital	0.566***	0.566***	0.572***	0.564***	0.565***	0.569***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Infrastructure		0.312***	0.311***		0.604***	0.621***
		(0.002)	(0.002)		(0.003)	(0.003)
Infrastructure*High			0.0260***			0.027***
			(0.000)			(0.000)
# of obs.	1,346,842	1,346,842	1,346,842	1,346,842	1,346,842	1,346,842
R-squared	0.554	0.565	0.586	0.552	0.564	0.588

model	TFPQ			TFPQ-spillover		
	(1)	(2)	(3)	(1)	(2)	(3)
Productivity	0.461***	0.529***	0.362***	0.430***	0.497***	0.332***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Capital	0.562***	0.563***	0.562***	0.561***	0.562***	0.559***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Infrastructure		0.378***	0.439***		0.721***	0.863***
		(0.002)	(0.002)		(0.004)	(0.004)
Infrastructure*High			0.0268***			0.027***
			(0.000)			(0.000)
# of obs.	1,346,842	1,346,842	1,346,842	1,346,842	1,346,842	1,346,842
R-squared	0.551	0.567	0.589	0.550	0.566	0.590

Note:

1. Industry dummies and year dummies are included in all regressions.
2. HIGH: dummy variable, $HIGH_{it-1}$ = 1 (0) if productivity is below (beyond) median.
3. Lagged values of explanatory variables are used in regressions.
4. *** p<0.01, ** p<0.05, * p<0.1

Our Answers to the Research Questions

- What is average rate of return of public infrastructure investment?
  - 28.3% to 9.2% in a TFPR model with/without spillover effects
  - The average rate of return of private investment lies in between.
- Is it a short-run demand effect or long-run productivity effect?
  - 7.2% to 2.5% in a TFPQ model with/without spillover effects
  - Short-run demand effects account more than two-thirds.
- What are the mechanisms for such investment to be productive?
  - Facilitating resource reallocation via the trade channel
  - Increasing aggregate productivity while some firms may lose

Questions Beyond This Paper

- During our sample period
  - Overall efficiency vs inefficiency in some projects or regions
- Beyond our sample period, we have to be very cautious on concluding whether
  - Has China over-invested or under-invested in infrastructure?
  - Further investment may be subject to decreasing returns;
  - Further investment may benefit from network externalities.
- A complete evaluation on efficiency, optimality and feasibility:
  - Schemes and designs of public finance
  - Institutions and incentives from a perspective of political economy