Technology Transfer and Early Industrial Development: Evidence from the Sino-Soviet Alliance

Michela Giorcelli
UCLA, NBER and CEPR

Bo Li
Tsinghua University

NBER DAE
Spring Annual Meeting
March 26, 2022

Motivation

International technology and knowledge transfers key elements of economic development

- Foreign technology boosts firm outcomes (Pavcnik, 2002; Goldberg at el., 2009; Bloom et al., 2013)
- Used to push industrialization in developing countries (Hoekman et al., 2004; Robinson, 2009)
- Diffusion of state-of-the-art capital goods (Stokey, 2020)

In early stage of industrialization lack of industry specific knowledge

- "Tacit" component hard to transfer
- Essential for pioneering firms to succeed (Mostafa and Klepper, 2018)
- Extensive on-the-job training from foreign companies (Chandra, 2006)

Little understanding on which interventions work in fostering industrial development

- Lack of long-term data on firm performance
- Causal effect? Limited natural variation of interventions delivery
- Technology and knowledge transfer often occurred simultaneously

This Paper: Sino-Soviet Alliance (1950-1960)

"156 Projects" → technologically advanced, large-scale, capital-intensive industrial facilities

- *Basic Transfer* : Duplicate whole Soviet plants and transfer of state-of-the-art machineries
- *Advanced Transfer* : Training of Chinese engineers and technicians and technical assistance
- Best technology in Soviet Union, in world for steel and iron (Lardy, 1995; Gangchalianke, 2002)

Data collection

- 139 projects approved and signed in 1950-1957
- 304 plant-level data in steel industry in 1949-2000
- Firm-level data in 1985 and 1998-2013

Identification: Unexpected delays on Soviet side + Split in 1960, after plants were built

- Received and retained Soviet machineries → *basic plants*
- Received and retained Soviet machineries + training → *advanced plants*
- No transfer, with domestic traditional technology → *comparison plants*

Preview of the Results

Basic transfer: Short-lived effects

- + 15% output increase in 6 years relative to comparison plants
- No significant impact after 20 years
- Estimated life-cycle of capital

Advanced transfer: Long-lasting effects and technology development

- + 20% after 20 years, + 49% after 40 years relative to basic plants
- Replace Soviet capital with home-produced modern machineries
- Less foreign capital import, more exports after 1978

Spillover effects driven by advanced transfer

- Higher productivity in related firms and same technology adoption
- Since late 1990s, productivity advantage for privatized firms
- Higher level of STEM degrees and technical schools in counties with advanced transfer

Contribution to the Literature

Role of Industrial Policy and Technology Transfer on Structural Transformation Mitrunen, 2019; Choi and Levchenko, 2021; Kim et al., 2021; Lane, 2021

Knowledge diffusion and on-the-job training Keller and Yeaple, 2013; Yeaple, 2013; Mosafa and Keppler, 2018; Giorcelli, 2019; Hardy and Jamie, 2020; Guillouët et al., 2021

Technology Diffusion in Developing Countries Pavcnik, 2002; Mel et al., 2008; Goldberg et al., 2010; Bloom et al., 2013; Bruhn et al., 2018; Atkin et al., 2017, Bloom et al., 2020; Juhász et al., 2020

Spillover effects *New large plants*: Javorcik et al., 2008; Greenstone et al., 2010; Alfaro-Urena et al., 2019; *Worker Mobility*: Stoyanov et al., 2012; *Managerial knowledge*: Bloom et al., 2020; Bianchi and Giorcelli, 2021; *Sectorial industrial policy:* Liu, 2019; Heblich et al., 2020; Lane, 2021

Overview

- Historical Setting
- Data
- Empirical Strategy
- Effects of Technology Transfer on Firm Outcomes
- Spillover Effects
- Conclusions

Overview

- Historical Setting
- Data
- Empirical Strategy
- Effects of Technology Transfer on Firm Outcomes
- Spillover Effects
- Conclusions

The Technology Transfer Program

In 1949 China's economy largely premodern → Soviet technology transfer (Lardy, 1995)

- Several agreements between 1950 and 1957
- "156 projects" for technologically advanced, large-scale, capital-intensive industrial facilities
- 45% of Chinese GDP in 1949; 144% of Chinese industrial production in 1949

Basic technology transfer

- Importation of whole Soviet plants; installation of state-of-the-art machinery and equipment
- Best technology in Soviet Union; best in the world for iron and steel
- Help in selecting plants site, supplying the design, supervising construction

Advanced knowledge transfer

- Training of Chinese personnel: engineers and high-skilled technicians
- Wide range of topics from the fundamental theory to specific firm practices
- Sharing of engineering designs, product designs (~4,000) and other technical data

Anshan Iron and Steel Company

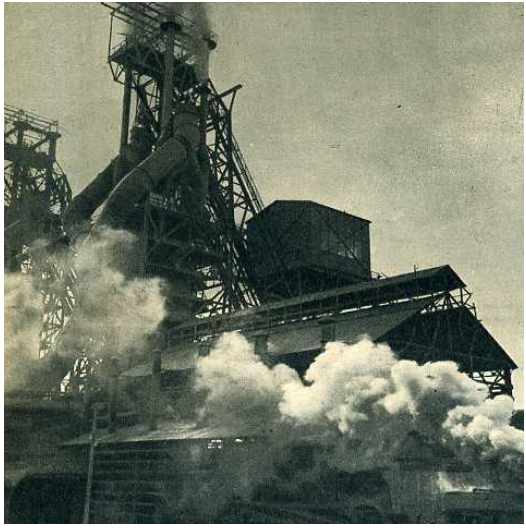
"The eldest son of the steel industry of the People's Republic of China"

Notes: Anshan Iron and Steel Company built starting in 1952 under the "Agreement on Technical Assistance on the Restoration and Reconstruction of Anshan Iron and Steel" signed on March 27, 1950. *Source*: The Memoir of Workers at Ansteel.

Arrival of Soviet Experts in 1952

Notes: Arrival of the Soviet engineer Maximoff at the Anshan Iron and Steel Company in 1952. *Source*: The Memoir of Workers at Ansteel.

First Blast Furnace Started Working in 1953

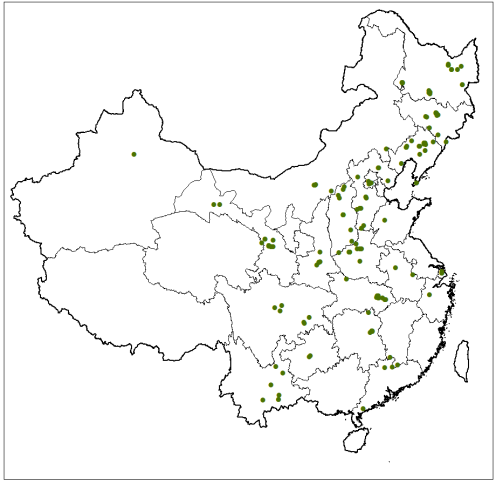


Notes: First Soviet-imported blast furnace in Anshan using Kolesnikov's advanced operating methods in 1953, that only took 6 and a half hours to produce the steel. *Source*: The Memoir of Workers at Ansteel.

Technical Assistance Provided by Soviet Engineers

Notes: Soviet electrical engineer Zhuowugnodny explaining Anshan high-skilled technicians how to use the blast furnace. *Source*: The Memoir of Workers at Ansteel.

Location of Technology Transfer Projects



Notes: Location of the 139 technology transfer approved projects. *Source*: National Archives Administration of China.

Substantial Delays in Completion of "156 Projects"

Machinery, equipment and designs arrived or started operations later than planned

- Constraints on the Soviet production capacity (Filatov, 1975)

  Fire in Red October Factory blocked shipment to Benxi Iron Steel

- Too few Soviet experts to visit Chinese plants and translators (Filatov, 1980)

  Team for Fushun Aluminum Plant redirected to Volkhov due to unexpected breakdown
  Team for Changchun First Automotive Plant had to wait for translators

- Miscommunication between Soviet and Chinese experts (Kiselev, 1960)

  Soviet designs did not fit Jilin Plant: initial misunderstanding, follow-up letters lost

In 1960 Sino-Soviet Split suddenly ended the technology transfer, after plants were built

- Received and retained Soviet machineries $\rightarrow$ *Basic Plants*
- Received and retained Soviet machineries + training $\rightarrow$ *Advanced Plants*
- No transfer, with domestic traditional technology $\rightarrow$ *Comparison Plants*

Overview

- Historical Setting
- Data
- Empirical Strategy
- Effects of Technology Transfer on Firm Outcomes
- Spillover Effects
- Conclusions

Data Collection

Technology transfer projects from *National Archives Administration of China*

- Project name, industry, firm location, starting dates, size, capacity, # workers
- 139 approved projects: 46 basic, 47 advanced, 46 comparison

Plant- and firm-level outcomes

- Steel industry (1949-2000) from *Steel Association Survey*
  - Matched 304 plants over 20 firms, product quantities, quality, technology in use
- In 1985 from *Second Industrial Survey*
  - Name, address, establishment year, total output, employees, fixed investment, exports
- In 1998-2013 from *China Industrial Enterprises* database
  - Firm output, capital investment, employees, profits, ownership structure

Industrial production at provincial level from *Statistical Yearbooks* (1949-2013)

- Total output, average output, number of firms and workers, wages
- ▸ Industries ▸ Ownership ▸ Location

Data Manipulation and Cross-Check

Data manipulation by plant supervisors?

- Steel Annual Reports highly monitored by industrial peers
- Strongly reduced risk of manipulation

Government incentives to inflate advanced or basic plants performance?

- Wanted to tie up loose ends with Soviet Union
- If any manipulation, in favor of comparison plants

Data cross-check

- Clark (1995) studies of Chinese steel industry by visiting plants
- Assessing "credible" production based on capital in use
- $\rightarrow$ Steel Annual Reports are accurate

Overview

- Historical Setting
- Data
- Empirical Strategy
- Effects of Technology Transfer on Firm Outcomes
- Spillover Effects
- Conclusions

Empirical Specification

$$\text{outcome}_{it} = \alpha_i + \delta_t + \sum_{\tau=-5}^{40} \beta_t(\text{Basic}_i \cdot \text{Years after Transfer}{=}\tau_{it}) + \sum_{\tau=-5}^{40} \gamma_t(\text{Advanced}_i \cdot \text{Years after Transfer}{=}\tau_{it}) + \epsilon_{it}$$

- Outcome_{it}: logged output and TFP of plant i at time t
- Basic_i: indicator for plants that received Soviet capital
- Advanced_i: indicator for plants that received also technical assistance
- Years after Treatment$=\tau_{it}$: τ calendar years before/after plant i got Soviet transfer
  - Assumed to be 1960 for comparison plants
- α_i: plant fixed effects
- δ_t: time fixed effects
- Standard errors clustered at the plant level

Identification Assumptions

Transfer eventually received orthogonal to project characteristics or potential success

- β_t measures the effects on plant performance of a basic transfer relative to no transfer
- γ_t measures the additional effect of an advanced transfer on top of a basic transfer

Supportive empirical evidence

- Balancing test between basic, advanced, and comparison projects and counties
- Industry and location do not predict participation transfer eventually received
- Balancing test between basic, advanced, and comparison plants
- Tests for pre-trends in plant performance

Reallocation from treated to comparison projects?

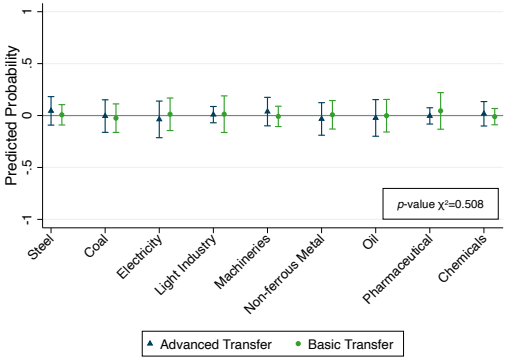
- Before the split: Machinery and experts were project-specific (Filatov, 1975)
- After the split: No evidence + harmful for treated projects (Borisov and Koloskov, 1980)
- High-skilled workers employed locally (Hirata, 2018); Migration highly restricted

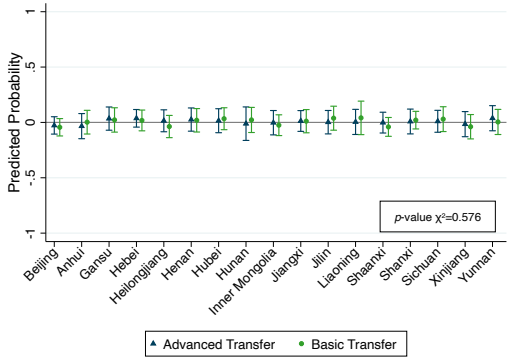
No Significant Differences in Basic, Advanced and Comparison Projects

	Basic (1)	Advanced (2)	Comparison (3)	*p*-value (4)
Approval Year	1953.57	1953.44	1953.26	0.609
Start Year	1955.24	1955.30	1955.13	0.762
Planned Investment (m)	594.08	577.97	569.02	0.864
Actual Investment (m)	526.99	550.67	571.59	0.615
Planned N. Workers (k)	38.72	40.19	40.81	0.768
Actual N. Workers (k)	39.94	40.05	38.95	0.924
Expected Equipment Value (m)	259.01	260.05	258.98	0.993
Expected Length	5.77	5.54	5.63	0.720
Expected Capacity (m tons)	1.63	1.69	1.71	0.934
N	46	47	46	139

Notes. *Basic projects* received Soviet machinery (col. 1); *Advanced projects* received Soviet machinery and training (col. 2); *Comparison projects* did not receive any Soviet transfer and were completed with domestic traditional technology (col. 3). Col. 4 reports *p*-values of ANOVA test of mean equality among all projects. Data are provided at the project-level from the National Archives Administration of China. ▸ More

Industry and Provinces Do Not Predict Treatment





Notes. Predicted probabilities (marginal effects) and 95% confidence intervals of receiving a basic or an advanced transfer relative to the baseline of not receiving any Soviet transfer regressed on industry and province indicators in a multinomial logit model. *p*-value of χ^2 tests of joint equality of all coefficients to zero are reported in each panel. Data are provided at the project-level from the National Archives Administration of China. ▸ More

Similar Characteristics of Hosting Counties in 1953

	Log Total Firms (1)	Log Population (2)	Employment Share (3)	Log Gvt. Funds (4)
Basic	0.018	-0.013	0.006	0.003
	(0.013)	(0.011)	(0.014)	(0.006)
Advanced	-0.015	0.012	0.004	0.007
	(0.016)	(0.013)	(0.011)	(0.012)
Observations	81	81	81	81

Notes. OLS regressions predicting county-level outcomes in 1953 in counties that hosted the 156 Projects. *Basic* is an indicator for counties that hosted basic projects that received Soviet machinery and equipment; *Advanced* is an indicator for advanced projects that received Soviet machinery and equipment and training. Data are provided at the county-level from the People's Republic of China Population Digest in 1953.

No Baseline Differences in Plant Performance at Time=-1

	Basic	Advanced		Basic	Advanced
Steel Production (m tons)	2.038	7.022	Employees per Plant (k)	0.110	0.242
	(7.714)	(7.669)		(0.280)	(0.296)
Current Assets (m)	1.999	0.262	Engineers (k)	0.002	0.016
	(1.870)	(0.348)		(0.021)	(0.021)
Annual Sales (m)	-0.550	0.458	High-Skilled Technicians (k)	-0.207	-0.104
	(0.664)	(0.903)		(0.234)	(0.095)
Value Added (m)	-0.655	0.893	Loans	0.673	0.534
	(1.146)	(1.081)		(0.587)	(0.459)
Productivity (log TFPQ)	-0.058	0.039	Transfers	-0.197	-0.274
	(0.112)	(0.068)		(0.677)	(0.502)
Observations	304	304	Observations	304	304

Notes. Coefficients estimated from regressing each plant variable in the year before Soviet transfer on an indicator for receiving the basic transfer (col. 1), an indicator for receiving the advanced transfer (col. 2), and a full set of firm fixed effects (not reported). Data are provided at the plant-level from the Steel Association Reports. Log $TFPQ = \log TFPR - \tilde{p}$ where TFPR uses Gandhi's (2020) method and $\tilde{p}$ is the revenue share weighted average of the prices of plant products; *Annual Sales, Value Added, Loans and Transfers* are in 2020 US$ millions.

No Differential Pre-Trends Between Time=-5 and Time=-1

	Log Steel		Log TFPQ		Log Assets		Log Employees	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Basic * Trend	-0.001	-0.002	0.006	0.007	-0.004	-0.007	0.002	0.002
	(0.001)	(0.003)	(0.009)	(0.008)	(0.004)	(0.009)	(0.003)	(0.004)
Advanced * Trend	0.005	0.004	0.002	-0.002	-0.005	-0.003	-0.003	-0.005
	(0.008)	(0.007)	(0.003)	(0.004)	(0.007)	(0.004)	(0.004)	(0.008)
Time Trend	-0.009	-0.003	-0.002	-0.003	-0.004	-0.005	0.009	-0.003
	(0.010)	(0.004)	(0.002)	(0.006)	(0.006)	(0.008)	(0.012)	(0.006)
Observations	2,114	2,114	2,114	2,114	2,114	2,114	2,114	2,114
Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	Yes	No	Yes	No	Yes	No	Yes

Notes. Coefficients estimated from regressing each plant variable in the five years before Soviet transfer on an indicator for receiving the basic transfer or the advanced transfer interacted with linear time trend. Data are provided at the plant-level from the Steel Association Reports. *Log Steel* is in m tons; log $TFPQ = \log TFPR - \tilde{p}$ where TFPR uses Gandhi's (2020) method and $\tilde{p}$ is the revenue share weighted average of the prices of plant products; *Log Assets* is in 2020 US$ millions; *Log Employees* is logged k employees.

Reallocation across Basic, Advanced and Comparison Plants?

Transfer eventually received orthogonal to project characteristics or potential success

- β_t measures the effects on plant performance of a basic transfer relative to no transfer
- γ_t measures the additional effect of an advanced transfer on top of a basic transfer

Supportive empirical evidence

- Balancing test between basic, advanced, and comparison projects and counties
- Industry and location do not predict participation transfer eventually received
- Balancing test between basic, advanced, and comparison plants
- Tests for pre-trends in plant performance

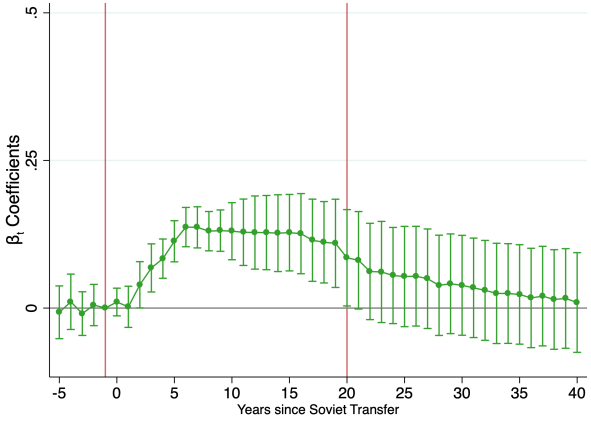
Reallocation from treated to comparison projects?

- Before the split: Machinery and experts were project-specific (Filatov, 1975)
- After the split: No evidence + harmful for treated projects (Borisov and Koloskov, 1980)
- High-skilled workers employed locally (Hirata, 2018); Migration highly restricted

Overview

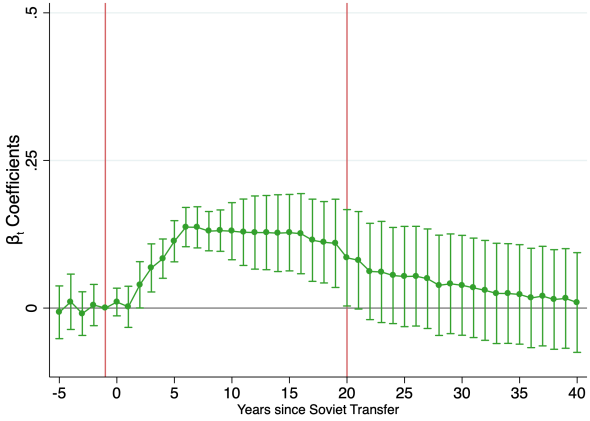
- Historical Setting
- Data
- Empirical Strategy
- Effects of Technology Transfer on Firm Outcomes
  - Plants in Steel Industry, 1949-2000
  - Development of New Technologies
  - Alternative Explanations and Robustness Checks
- Spillover Effects
- Conclusions

Plant Output: +15% in 6 Years in Basic Plants wrt Comparison Plants



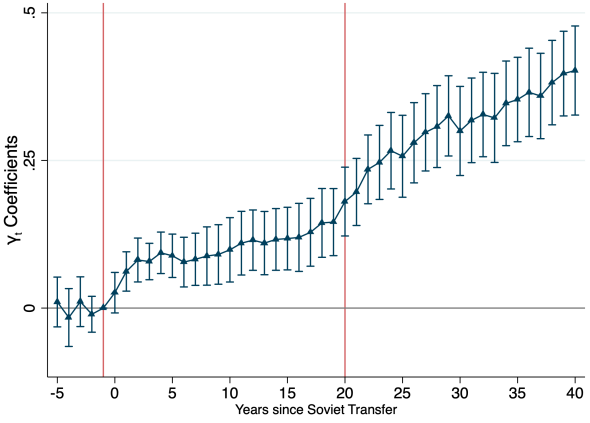
Notes. Annual β_t coefficients estimated from the equation 1 for plant output, measured in logged m tons of steel. Standard errors are clustered at the plant level. Data are provided at the plant level from the Steel Association Reports from 1949 to 2000.

Plant Output: No Significant Effects after 20 Years



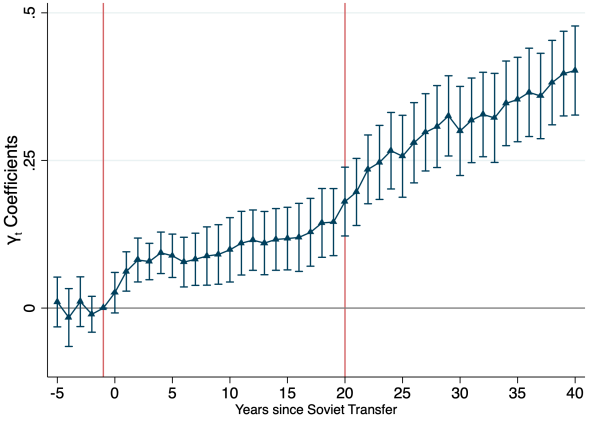
Notes. Annual β_t coefficients estimated from the equation 1 for plant output, measured in logged m tons of steel. Standard errors are clustered at the plant level. Data are provided at the plant level from the Steel Association Reports from 1949 to 2000.

Plant Output: +20% in 20 Years in Advanced Plants wrt Basic Plants



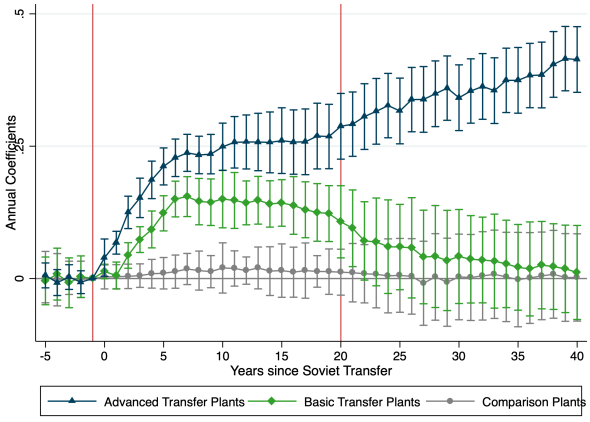
Notes. Annual γ_t coefficients estimated from the equation 1 for plant output, measured in logged m tons of steel. Standard errors are clustered at the plant level. Data are provided at the plant level from the Steel Association Reports from 1949 to 2000.

Plant Output: +49% in 40 Years in Advanced Plants wrt Basic Plants



Notes. Annual γ_t coefficients estimated from the equation 1 for plant output, measured in logged m tons of steel. Standard errors are clustered at the plant level. Data are provided at the plant level from the Steel Association Reports from 1949 to 2000.

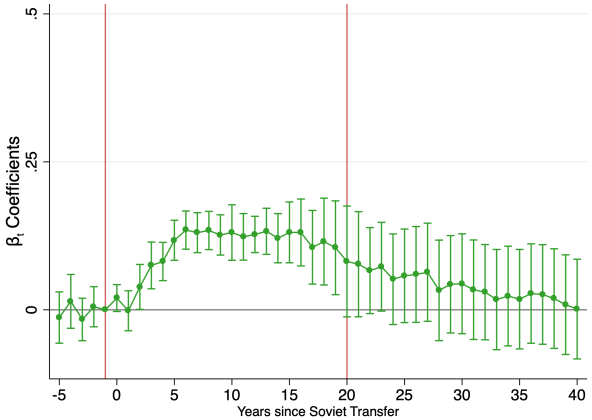
Effects on Plant Output Driven by Advanced and Basic Plants



Notes. Single differences estimated from the equation 1 for plant output, measured in logged m tons of steel. Standard errors are clustered at the plant level. Data are provided at the plant level from the Steel Association Reports from 1949 to 2000.

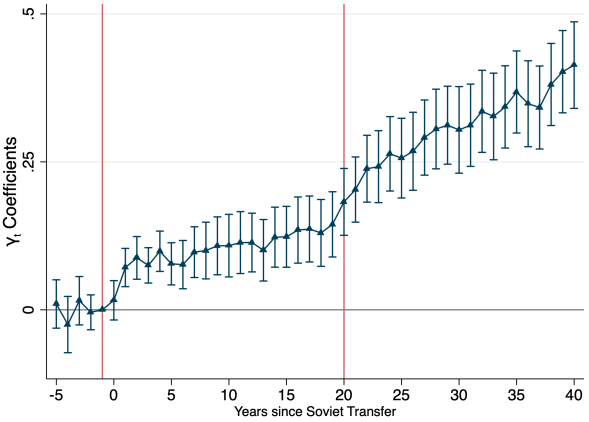
▸ Comparison Plants

Similar Effects on TFP for Basic Plants wrt Comparison Plants



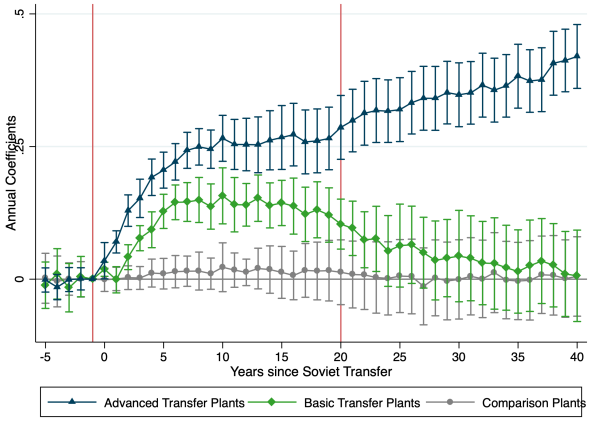
Notes. Annual β_t coefficients estimated from the equation 1 for plant TFP, computed as $\log TFPQ = \log TFPR - \tilde{p}$ where TFPR is calculated using the Gandhi's (2020) method and $\tilde{p}$ is the revenue share weighted average of the prices of plant products. Standard errors are clustered at the plant level. Data are provided at the plant level from the Steel Association Reports from 1949 to 2000.

Similar Effects on TFP for Advanced Plants wrt Basic Plants



Notes. Annual γ_t coefficients estimated from the equation 1 for plant TFP, computed as $\log TFPQ = \log TFPR - \tilde{p}$ where TFPR is calculated using the Gandhi's (2020) method and $\tilde{p}$ is the revenue share weighted average of the prices of plant products. Standard errors are clustered at the plant level. Data are provided at the plant level from the Steel Association Reports from 1949 to 2000.

Effects on Plant TFP Driven by Advanced and Basic Plants



Notes. Single differences estimated from the equation 1 for plant TFP, computed as $\log TFPQ = \log TFPR - \tilde{p}$ where TFPR is calculated using the Gandhi's (2020) method and $\tilde{p}$ is the revenue share weighted average of the prices of plant products. Standard errors are clustered at the plant level. Data are provided at the plant level from the Steel Association Reports from 1949 to 2000.

▸ Comparison Plants

Overview

- Historical Setting
- Data
- Empirical Strategy
- Effects of Technology Transfer on Firm Outcomes
  - Plants in Steel Industry
  - Mechanisms of Persistence
  - Alternative Explanations and Robustness Checks
- Spillover Effects
- Conclusions

Advanced Plants: New Technologies in 1960s-1970s

	Prob. Oxy.	Prob. Cast.	Log Import Capital	Log Exports	Log Int. St.
Advanced * Year 1	0.003	0.008	0.006	0.005	0.004
	(0.010)	(0.011)	(0.008)	(0.007)	(0.006)
Advanced * Year 5	0.252***	0.019	0.007	0.003	0.007
	(0.041)	(0.013)	(0.011)	(0.006)	(0.009)
Advanced * Year 10	0.345***	0.267***	0.009	0.004	0.002
	(0.053)	(0.051)	(0.011)	(0.006)	(0.0063)
Advanced * Year 20	0.651***	0.784***	-0.059***	0.067***	0.040***
	(0.151)	(0.143)	(0.011)	(0.012)	(0.010)
Advanced * Year 30	0.237***	0.255***	-0.133***	0.298***	0.367***
	(0.049)	(0.048)	(0.033)	(0.051)	(0.053)
Advanced * Year 40	0.229***	0.223***	-0.184***	0.375***	0.413***
	(0.044)	(0.045)	(0.053)	(0.065)	(0.068)
Observations	12,160	12,160	12,160	12,160	12,160

Notes. Prob. Oxy and *Prob. Cast.* are one for plants using the basic oxygen converters and the continuous casting furnaces. *Log Import Capital, Exports* and *Int. St.* are logged values of foreign imported capital, firm exports and quantity of steel that meet international standards. Regressions include plant and year fixed effects. Standard errors are clustered at the plant level. ***p<0.01, **p<0.05, *p<0.1.

Advanced Plants: Less Foreign Capital; More Exports after 1978

	Prob. Oxy.	Prob. Cast.	Log Import Capital	Log Exports	Log Int. St.
Advanced * Year 1	0.003	0.008	0.006	0.005	0.004
	(0.010)	(0.011)	(0.008)	(0.007)	(0.006)
Advanced * Year 5	0.252***	0.019	0.007	0.003	0.007
	(0.041)	(0.013)	(0.011)	(0.006)	(0.009)
Advanced * Year 10	0.345***	0.267***	0.009	0.004	0.002
	(0.053)	(0.051)	(0.011)	(0.006)	(0.0063)
Advanced * Year 20	0.651***	0.784***	-0.059***	0.067***	0.040***
	(0.151)	(0.143)	(0.011)	(0.012)	(0.010)
Advanced * Year 30	0.237***	0.255***	-0.133***	0.298***	0.367***
	(0.049)	(0.048)	(0.033)	(0.051)	(0.053)
Advanced * Year 40	0.229***	0.223***	-0.184***	0.375***	0.413***
	(0.044)	(0.045)	(0.053)	(0.065)	(0.068)
Observations	12,160	12,160	12,160	12,160	12,160

Notes. Prob. Oxy and *Prob. Cast.* are one for plants using the basic oxygen converters and the continuous casting furnaces. *Log Import Capital, Exports* and *Int. St.* are logged values of foreign imported capital, firm exports and quantity of steel that meet international standards. Regressions include plant and year fixed effects. Standard errors are clustered at the plant level. ***p<0.01, **p<0.05, *p<0.1.

No Differential Effects for Basic Plants

	Prob. Oxy.	Prob. Cast.	Log Import Capital	Log Exports	Log Int. St.
Basic * Year 1	0.006	0.005	0.002	0.001	0.005
	(0.005)	(0.009)	(0.006)	(0.004)	(0.007)
Basic * Year 5	0.009	0.007	0.004	0.006	0.005
	(0.010)	(0.008)	(0.006)	(0.007)	(0.008)
Basic * Year 10	0.009	0.006	0.003	0.008	0.006
	(0.010)	(0.008)	(0.004)	(0.011)	(0.012)
Basic * Year 20	0.007	0.010	0.008	0.011	0.014
	(0.009)	(0.014)	(0.011)	(0.016)	(0.012)
Basic * Year 30	0.007	0.011	0.007	0.006	0.004
	(0.009)	(0.015)	0.001	0.003	0.009
Basic * Year 40	0.008	0.007	0.009	0.006	0.003
	(0.009)	(0.009)	(0.011)	(0.007)	(0.009)
Observations	12,160	12,160	12,160	12,160	12,160

Notes. Prob. Oxy and *Prob. Cast.* are one for plants using the basic oxygen converters and the continuous casting furnaces. *Log Import Capital, Exports* and *Int. St.* are logged values of foreign imported capital, firm exports and quantity of steel that meet international standards. Regressions include plant and year fixed effects. Standard errors are clustered at the plant level. ***p<0.01, **p<0.05, *p<0.1.

Overview

- Historical Setting
- Data
- Empirical Strategy
- Effects of Technology Transfer on Firm Outcomes
  - Plants in Steel Industry
  - Development of New Technologies
  - Alternative Explanations and Robustness Checks
- Spillover Effects
- Conclusions

Alternative Explanations and Robustness Checks

- Government Loans and Transfers Go
- Plant Proximity to Roads and Railroads Go
- Political Connections Go
- Effects in 1985 and in 1998-2013 Go
- Alternative Fixed Effects Go
- "Interaction-weighted" (IW) estimators for two-way fe (Sun and Abraham, 2021) Go
- Alternative Timing Go
- Alternative Clustering Go
- Data Cross-Checking (Clark, 1995) Go
- Selection on Unobservables Go

Outline

- Historical Setting
- Data
- Empirical Strategy
- Effects of Technology Transfer on Firm Outcomes
- Spillover Effects
  - Horizontal and Vertical Spillovers
  - Role of Institutional Changes
- Conclusions

Spillovers across Plants within Firm of Advanced Plants

	Log Steel	Log TFPQ	Prob. Oxy.	Prob. Cast.	Log Exports	Log Int. St.
Basic * Post	0.031	0.027	-0.003	0.008	0.008	0.010
	(0.041)	(0.029)	(0.011)	(0.015)	(0.008)	(0.013)
Advanced * Post	0.223***	0.199***	0.425***	0.532***	0.002	0.005
	(0.049)	(0.035)	(0.078)	(0.061)	(0.009)	(0.007)
Basic * Post 1978	0.007	0.004	-0.005	-0.005	0.009	0.012
	(0.009)	(0.005)	(0.008)	(0.008)	(0.013)	(0.011)
Advanced * Post 1978	0.123***	0.198***	0.225***	0.233***	0.203***	0.258***
	(0.039)	(0.041)	(0.055)	(0.042)	(0.047)	(0.062)
Observations	12,346	12,346	12,346	12,346	12,346	12,346

Notes. *Basic/Advanced* is 1 for plants in the same firm as basic/advanced plants. *Log Steel, Exports* and *Int. St.* are in m tons; $\text{Log}\,TFPQ = \log TFPR - \tilde{p}$ where TFPR uses Gandhi's (2020) method and $\tilde{p}$ is the revenue share weighted average of the prices of plant products. *Prob. Oxy* and *Prob. Cast.* is 1 for plants with basic oxygen converters and continuous casting. Regressions include plant and year fixed effects and basic and advanced indicators, not reported. Standard errors are clustered at plant level. ***p<0.01, **p<0.05, *p<0.1.

Horizontal Spillovers in Counties with Advanced Plants

	Log Steel	Log TFPQ	Prob. Oxy.	Prob. Cast.	Log Exports	Log Int. St.
Basic * Post	0.006	0.011	0.009	0.012	0.007	0.012
	(0.008)	(0.015)	(0.010)	(0.013)	(0.011)	(0.013)
Advanced * Post	0.122***	0.117***	0.308***	0.319***	0.016	0.019
	(0.017)	(0.015)	(0.111)	(0.123)	0.011)	(0.016)
Basic * Post 1978	-0.015	0.022	0.004	0.006	0.005	0.009
	(0.020)	(0.021)	(0.010)	(0.011)	(0.008)	(0.012)
Advanced * Post 1978	0.022***	0.018***	0.033***	0.045***	0.187***	0.201***
	(0.007)	(0.006)	(0.012)	(0.009)	(0.051)	(0.065)
Observations	13,550	13,550	13,550	13,550	13,550	13,550

Notes. *Basic/Advanced* is 1 for plants in the same county and sector as basic/advanced plants. *Log Steel, Exports* and *Int. St.* are in m tons; $\text{Log}TFPQ = \log TFPR - \tilde{p}$ where TFPR uses Gandhi's (2020) method and $\tilde{p}$ is the revenue share weighted average of the prices of plant products. *Prob. Oxy* and *Prob. Cast.* is 1 for plants with basic oxygen converters and continuous casting. Regressions include plant and year fixed effects and basic and advanced indicators, not reported. Standard errors are clustered at plant level. ***p<0.01, **p<0.05, *p<0.1.

Vertical: More Output in Counties with Basic and Advanced Plants

	Log Steel	Log TFPQ	Prob. Oxy.	Prob. Cast.	Log Exports	Log Int. St.
Basic * Post	0.133***	0.011	0.009	0.006	0.016	0.012
	(0.022)	(0.014)	(0.011)	(0.009)	(0.015)	(0.016)
Advanced * Post	0.152***	0.132***	0.106***	0.100***	0.004	0.006
	(0.035)	(0.039)	(0.031)	(0.025)	(0.005)	(0.009)
Basic * Post 1978	-0.015	0.022	0.004	0.006	0.009	0.011
	(0.020)	(0.021)	(0.010)	(0.011)	(0.010)	(0.025)
Advanced * Post 1978	0.034***	0.028***	0.029***	0.037***	0.145***	0.138***
	(0.008)	(0.007)	(0.008)	(0.006)	(0.032)	(0.031)
Observations	15,340	15,340	15,340	15,340	15,340	15,340

Notes. *Basic/Advanced* is 1 for plants in the same county and upstream/downstream of basic/advanced plants. *Log Steel, Exports* and *Int. St.* are in m tons; Log$TFPQ$ = log $TFPR - \tilde{p}$ where TFPR uses Gandhi's (2020) method and $\tilde{p}$ is the revenue share weighted average of the prices of plant products. *Prob. Oxy* and *Prob. Cast.* is 1 for plants with basic oxygen converters and continuous casting. Regressions include plant and year fixed effects and basic and advanced indicators, not reported. Standard errors are clustered at plant level. ***p<0.01, **p<0.05, *p<0.1.

More Productivity and Tech. Adoption in Counties with Advanced Plants

	Log Steel	Log TFPQ	Prob. Oxy.	Prob. Cast.	Log Exports	Log Int. St.
Basic * Post	0.133***	0.011	0.009	0.006	0.016	0.012
	(0.022)	(0.014)	(0.011)	(0.009)	(0.015)	(0.016)
Advanced * Post	0.152***	0.132***	0.106***	0.100***	0.004	0.006
	(0.035)	(0.039)	(0.031)	(0.025)	(0.005)	(0.009)
Basic * Post 1978	-0.015	0.022	0.004	0.006	0.009	0.011
	(0.020)	(0.021)	(0.010)	(0.011)	(0.010)	(0.025)
Advanced * Post 1978	0.034***	0.028***	0.029***	0.037***	0.145***	0.138***
	(0.008)	(0.007)	(0.008)	(0.006)	(0.032)	(0.031)
Observations	15,340	15,340	15,340	15,340	15,340	15,340

Notes. *Basic/Advanced* is 1 for plants in the same county and upstream/downstream of basic/advanced plants. *Log Steel, Exports* and *Int. St.* are in m tons; Log$TFPQ$ = log $TFPR - \tilde{p}$ where TFPR uses Gandhi's (2020) method and $\tilde{p}$ is the revenue share weighted average of the prices of plant products. *Prob. Oxy* and *Prob. Cast.* is 1 for plants with basic oxygen converters and continuous casting. Regressions include plant and year fixed effects and basic and advanced indicators, not reported. Standard errors are clustered at plant level. ***p<0.01, **p<0.05, *p<0.1.

Outline

- Historical Setting
- Data
- Empirical Strategy
- Effects of Technology Transfer on Firm Outcomes
- Spillover Effects
  - Horizontal and Vertical Spillovers
  - Role of Institutional Changes
- Conclusions

More Productive *Private* Firms in Counties with Advanced Plants

	Log Value Added	Log TFPR	Log Exports
Basic	0.013	-0.005	-0.012
	(0.025)	(0.018)	(0.015)
Advanced	0.011	-0.009	0.003
	(0.020)	(0.012)	(0.008)
Basic * Private	0.022	0.025	0.008
	(0.031)	(0.028)	(0.013)
Advanced * Private	0.215***	0.209***	0.134***
	(0.031)	(0.045)	(0.033)
Basic * Private * New	0.015	0.019	0.023
	(0.018)	(0.026)	(0.022)
Advanced * Private * New	0.033***	0.031***	0.050***
	(0.011)	(0.006)	(0.012)
Observations	560,123	560,123	560,123

Notes. *Basic/Advanced* is 1 for plants in the same county and related (same industry or upstream/downstream) to basic/advanced plants. Standard errors are clustered at the firm level. ***p<0.01, **p<0.05, *p<0.1.

Higher Share of Output Produced by *Private* Firms

	Share Privately Owned Firms			Share Private Output		
	All	Related	Unrelated	All	Related	Unrelated
	(1)	(2)	(3)	(4)	(5)	(6)
Basic	0.015	0.012	0.018	0.016	0.012	0.004
	(0.021)	(0.027)	(0.009)	(0.014)	(0.018)	(0.006)
Advanced	0.166***	0.161***	0.005	0.252***	0.242***	-0.011
	(0.020)	(0.015)	(0.005)	(0.044)	(0.049)	(0.013)
County-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,250	2,250	2,250	2,250	2,250	2,250

Notes. *Basic* is 1 for counties where basic plants were located; *Advanced* is 1 for counties where advanced plants were located. Standard errors are clustered at the county level. ***p<0.01, **p<0.05, *p<0.1.

Mechanisms: Higher Education and Human Capital

	STEM Universities	Technical Schools	College Graduates	High-Skilled Workers
	(1)	(2)	(3)	(4)
Basic	0.009	-0.010	0.015	0.007
	(0.013)	(0.012)	(0.021)	(0.011)
Advanced	0.104***	0.156***	0.133***	0.162***
	(0.034)	(0.041)	(0.030)	(0.035)
Prefecture-Year FE	Yes	Yes	Yes	Yes
Observations	1,296	1,296	1,296	1,296

Notes. *Basic* is 1 for counties where basic plants were located; *Advanced* is 1 for counties where advanced plants were located. Standard errors are clustered at the county level. ***p<0.01, **p<0.05, *p<0.1.

Overview

- Historical Setting
- Data
- Empirical Strategy
- Effects of Technology Transfer on Firm Outcomes
- Spillover Effects
- Conclusions

Conclusions

Effects of knowledge and technology transfers on early industrial development

- Persistent effects of advanced technology transfer
- Domestic technological upgrade and exports
- Substantial and persistent productivity spillover

Comparison with US aid program in Western Europe under Marshall Plan (1948–1958)

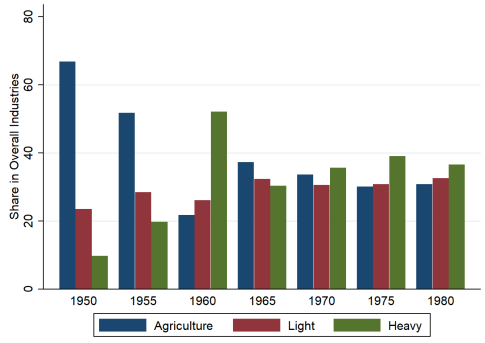
- Human capital transfer essential for having lost-lasting effects
- More limited spillover effects as targeted SMEs
- "156 Projects" shaped geographical distribution of Chinese industrialization

Policy implications

- Technology transfer programs widely used to promote industrialization
- Effects on top of simply imitation of foreign facilities with domestic technology
- Importance of foreign on-the-job training and know-how diffusion

BACK-UP SLIDES

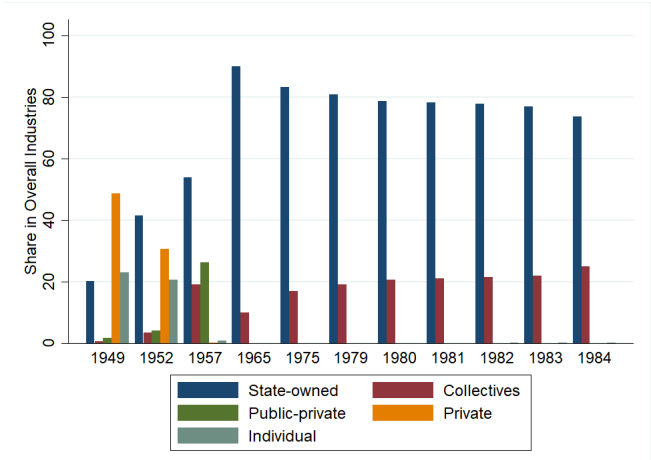
Industry Dynamics



Notes: Percentage of firms in the agriculture, manufacturing, and heavy industry respectively from 1949 to 1985.

Back

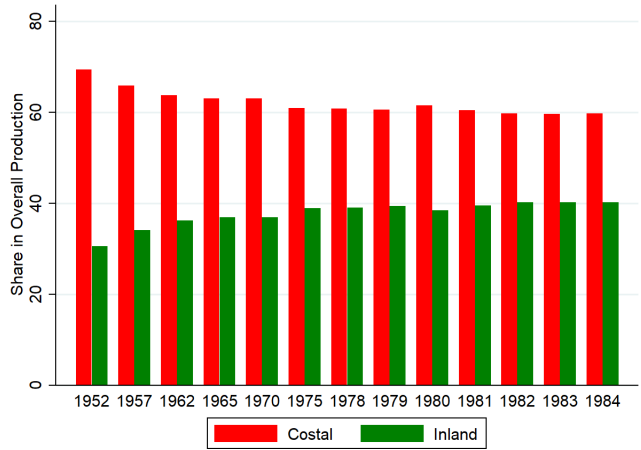
Ownership



Notes: Changes in the percentage of firms operate in the state-owned, collectives, public-private, private, and individual firms respectively from 1949 to 1985.

beamerreturnbuttonBack

Location



Notes: Production allocation between Coastal regions and Inland regions.

Back

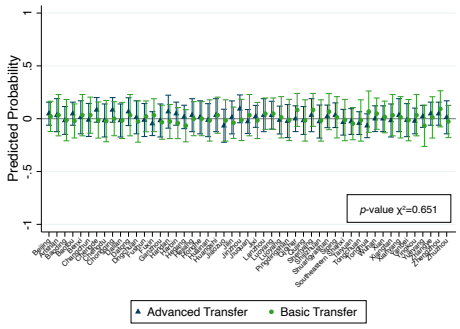
No Significant Differences in Basic, Advanced and Comparison Projects

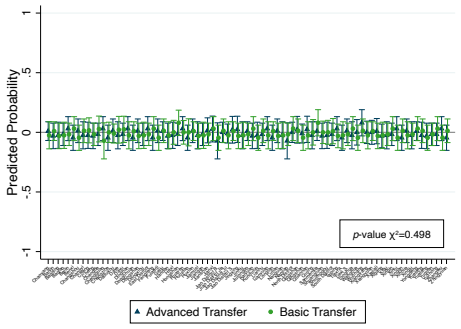
	Basic (1)	Advanced (2)	Comparison (3)	*p*-value (4)
Distance Border (km)	237.50	193.93	226.23	0.214
Distance Province (km)	66.60	69.78	69.72	0.893
Distance Coast (km)	518.73	572.23	541.45	0.576
Distance Treated Ports (km)	587.40	525.96	576.61	0.552
Distance Highway (km)	39.76	45.98	41.60	0.756
Distance Railway (km)	62.65	59.77	60.55	0.983
N	46	47	46	139

Notes. *Basic projects* received Soviet machinery (col. 1); *Advanced projects* received Soviet machinery and training (col. 2); *Comparison projects* did not receive any Soviet transfer and were completed with domestic traditional technology (col. 3). Col. 4 reports *p*-values of ANOVA test of mean equality among all projects. Data are provided at the project-level from the National Archives Administration of China.

Back

Prefecture Cities and Counties Do Not Predict Treatment





Notes. Predicted probabilities (marginal effects) and 95% confidence intervals of receiving a basic or an advanced transfer relative to the baseline of not receiving any Soviet transfer regressed on prefecture city and county indicators in a multinomial logit model. *p*-value of χ^2 tests of joint equality of all coefficients to zero are reported in each panel. Data are provided at the project-level from the National Archives Administration of China.

Back

Comparison Plants vs Other Steel Plants

	Log Output (1)	Log TFP (2)		Log Output (1)	Log TFP (2)
Comparison * Year 1	0.022	0.011	Comparison * Year 30	0.039***	0.014***
	(0.015)	(0.010)		(0.010)	(0.004)
Comparison * Year 10	0.033***	0.014***	Comparison * Year 40	0.035***	0.010***
	(0.011)	(0.005)		(0.007)	(0.003)
Comparison* Year 20	0.035***	0.015***			
	(0.007)	(0.005)			
Plant FE	Yes	Yes	Plant FE	Yes	Yes
Year FE	Yes	Yes	Year FE	Yes	Yes
Observations	36,220	36,220	Observations	36,220	36,220

Notes. *Comparison* is an indicator for plants built as part of the 156 Projects. *Log Output* is logged quantities (in m tons) of steel. *Log TFPQ* is logged productivity, computed as $\log TFPQ = \log TFPR - \tilde{p}$, where $\tilde{p}$ is the revenue share weighted average of the prices of plant products and TFPR is calculated using Gandhi et al. (2020)'s method. Data are provided at the plant level from the Steel Association Reports between 1949 and 2000. Standard errors are clustered at the plant-level.

◂ Back ◂ Back

Ruling Out Alternative Explanations: Government Transfers

	Log Loans	Log Transfer	Log Distance Road	Log Distance Railroad
Basic * Year 1	0.004	-0.009	-0.003	-0.005
	(0.006)	(0.010)	(0.006)	(0.007)
Basic * Year 10	-0.003	-0.008	-0.004	-0.003
	(0.004)	(0.008)	(0.006)	(0.005)
Basic * Year 40	-0.012	0.002	-0.003	0.009
	(0.011)	(0.004)	(0.004)	(0.017)
Advanced * Year 1	-0.008	-0.005	-0.007	-0.010
	(0.013)	(0.011)	(0.010)	(0.012)
Advanced * Year 10	0.002	-0.009	-0.005	-0.005
	(0.004)	(0.013)	(0.008)	(0.010)
Advanced * Year 40	-0.007	0.006	-0.009	0.004
	(0.008)	(0.015)	(0.011)	(0.006)

Notes. *Basic* is 1 for projects that received machinery only; *Advanced* is 1 for projects that received machinery + training. *Log Loans* and *Log Transfers* are measured in 2020 US$ millions. *Roads* and *Railroads* are distance in km from the closest roads and railroads. Standard errors are clustered at the plant level.

Back

Ruling Out Alternative Explanations: Accessibility

	Log Loans	Log Transfer	Log Distance Road	Log Distance Railroad
Basic * Year 1	0.004	-0.009	-0.003	-0.005
	(0.006)	(0.010)	(0.006)	(0.007)
Basic * Year 10	-0.003	-0.008	-0.004	-0.003
	(0.004)	(0.008)	(0.006)	(0.005)
Basic * Year 40	-0.012	0.002	-0.003	0.009
	(0.011)	(0.004)	(0.004)	(0.017)
Advanced * Year 1	-0.008	-0.005	-0.007	-0.010
	(0.013)	(0.011)	(0.010)	(0.012)
Advanced * Year 10	0.002	-0.009	-0.005	-0.005
	(0.004)	(0.013)	(0.008)	(0.010)
Advanced * Year 40	-0.007	0.006	-0.009	0.004
	(0.008)	(0.015)	(0.011)	(0.006)

Notes. *Basic* is 1 for projects that received machinery only; *Advanced* is 1 for projects that received machinery + training. *Log Loans* and *Log Transfers* are measured in 2020 US$ millions. *Roads* and *Railroads* are distance in km from the closest roads and railroads. Standard errors are clustered at the plant level.

Back

Ruling Out Alternative Explanations: Political Connections

	Secretaries			Mayors		
	Born City	Uni. City	Years Edu.	Born City	Uni. City	Years Edu.
Basic * Year 1	-0.004	-0.004	-0.005	-0.007	-0.008	-0.009
	(0.006)	(0.008)	(0.005)	(0.009)	(0.009)	(0.012)
Basic * Year 10	-0.002	-0.005	-0.004	-0.006	-0.006	-0.006
	(0.005)	(0.008)	(0.003)	(0.007)	(0.007)	(0.009)
Basic * Year 40	-0.002	-0.005	-0.010	-0.008	-0.008	-0.009
	(0.003)	(0.006)	(0.011)	(0.010)	(0.011)	(0.012)
Advanced*Year 1	-0.004	-0.003	-0.014	-0.009	-0.009	-0.008
	(0.006)	(0.005)	(0.012)	(0.014)	(0.010)	(0.009)
Advanced*Year 10	0.005	-0.002	-0.015	0.013	-0.011	-0.011
	(0.008)	(0.003)	(0.017)	(0.015)	(0.014)	(0.010)
Advanced*Year 40	-0.003	-0.007	-0.010	-0.010	-0.011	-0.009
	(0.008)	(0.008)	(0.012)	(0.012)	(0.013)	(0.013)

Notes. *Basic* is 1 for projects that received machinery only; *Advanced* is 1 for projects that received machinery + training. Standard errors are clustered at the plant level.

Back

Results in 1985 and 1998-2013

	Log Value Added		Log Workers		Log TFPR	
	(1)	(2)	(3)	(4)	(5)	(6)
Basic	0.047	0.008	0.006	0.008	0.038	0.006
	(0.043)	(0.010)	(0.008)	(0.016)	(0.023)	(0.011)
Advanced	0.347***	0.419***	0.003	0.009	0.333***	0.401***
	(0.053)	(0.069)	(0.005)	(0.010)	(0.048)	(0.058)
Sector-Province FE	Yes	No	Yes	No	Yes	No
Sector-Province-Year FE	No	Yes	No	Yes	No	Yes
Years	1985	1998-2013	1985	1998-2013	1985	1998-2013
Observations	139	2,085	139	2,085	139	2,085

Notes. Data are provided at the plant level from the Second Annual Survey in 1985 and from the China Industrial Enterprises database between 1998 and 2013. *Log Value Added* is measured in 2020 US$ millions; *Log Workers* is log k employees; *Log TFPR* is logged total factor productivity revenue computed with the Gandhi et al. (2020)'s method. Standard errors are clustered at the firm level. ***p<0.01, **p<0.05, *p<0.1.

Back

Output, Basic Plants: Alternative Fixed Effects

	Output				Output		
	(1)	(2)	(3)		(1)	(2)	(3)
Basic * Year 1	0.002	0.003	0.004	Basic * Year 30	0.039	0.041	0.040
	(0.018)	(0.019)	(0.017)		(0.044)	(0.045)	(0.047)
Basic * Year 10	0.130***	0.138***	0.141***	Basic * Year 40	0.009	0.008	0.010
	(0.025)	(0.022)	(0.024)		(0.043)	(0.041)	(0.043)
Basic * Year 20	0.085*	0.090*	0.088*				
	(0.046)	(0.050)	(0.049)				
Main Spec.	Yes	No	No	Main Spec.	Yes	No	No
Firm-Year FE	No	Yes	No	Firm-Year FE	No	Yes	No
County-Year FE	No	No	Yes	County-Year FE	No	No	Yes
Observations	12,160	12,160	12,160	Observations	12,160	12,160	12,160

Notes. Annual β_t coefficients estimated from the equation 1 for plant logged steel output under different fixed effects.

Back

Output, Advanced Plants: Alternative Fixed Effects

	Output				Output		
	(1)	(2)	(3)		(1)	(2)	(3)
Adv * Year 1	0.062***	0.065***	0.067***	Adv * Year 30	0.292***	0.293***	0.297***
	(0.017)	(0.015)	(0.019)		(0.038)	(0.036)	(0.039)
Adv * Year 10	0.098***	0.103***	0.107***	Adv * Year 40	0.402***	0.409***	0.413***
	(0.029)	(0.032)	(0.034)		(0.040)	(0.042)	(0.041)
Adv * Year 20	0.180***	0.184***	0.187***				
	(0.030)	(0.028)	(0.031)				
Main Spec.	Yes	No	No	Main Spec.	Yes	No	No
Firm-Year FE	No	Yes	No	Firm-Year FE	No	Yes	No
County-Year FE	No	No	Yes	County-Year FE	No	No	Yes
Observations	12,160	12,160	12,160	Observations	12,160	12,160	12,160

Notes. Annual γ_t coefficients estimated from the equation 1 for plant logged steel output under different fixed effects.

Back

Output, Basic Plants: Sun and Abraham (2021)

	Output			Output	
	(1)	(2)		(1)	(2)
Basic * Year 1	0.002	0.004	Basic * Year 30	0.039	0.040
	(0.018)	(0.017)		(0.044)	(0.047)
Basic * Year 10	0.130***	0.141***	Basic * Year 40	0.009	0.010
	(0.025)	(0.024)		(0.043)	(0.043)
Basic * Year 20	0.085*	0.088*			
	(0.046)	(0.049)			
Main Spec.	Yes	No	Main Spec.	Yes	No
IW Estimator	No	Yes	IW Estimator	No	Yes
Observations	12,160	12,160	Observations	12,160	12,160

Notes. Annual β_t coefficients estimated from the equation 1 for plant logged steel output using the Sun and Abraham (2021) IW estimators for two-way fixed effects.

Back

Output, Advanced Plants: Sun and Abraham (2021)

	Output			Output	
	(1)	(2)		(1)	(2)
Adv * Year 1	0.062***	0.067***	Adv * Year 30	0.292***	0.297***
	(0.017)	(0.019)		(0.038)	(0.039)
Adv * Year 10	0.098***	0.107***	Adv * Year 40	0.402***	0.413***
	(0.029)	(0.034)		(0.040)	(0.041)
Adv * Year 20	0.180***	0.187***			
	(0.030)	(0.031)			
Main Spec.	Yes	No	Main Spec.	Yes	No
IW Estimator	No	Yes	IW Estimator	No	Yes
Observations	12,160	12,160	Observations	12,160	12,160

Notes. Annual γ_t coefficients estimated from the equation 1 for plant logged steel output using the Sun and Abraham (2021) IW estimators for two-way fixed effects.

Back

Output, Basic Plants: Alternative Timing

	Output				Output		
	(1)	(2)	(3)		(1)	(2)	(3)
Basic * Year 1	0.002	0.006	0.005	Basic * Year 30	0.039	0.042	0.043
	(0.018)	(0.016)	(0.015)		(0.044)	(0.041)	(0.042)
Basic * Year 10	0.130***	0.139***	0.145***	Basic * Year 40	0.009	0.011	0.008
	(0.025)	(0.024)	(0.025)		(0.043)	(0.046)	(0.048)
Basic * Year 20	0.085*	0.087*	0.089*				
	(0.046)	(0.051)	(0.048)				
Main Spec.	Yes	No	No	Main Spec.	Yes	No	No
Imputed Year	First	Last	Mean	Imputed Year	First	Last	Mean
Observations	12,160	12,160	12,160	Observations	12,160	12,160	12,160

Notes. Annual β_t coefficients estimated from the equation 1 for plant logged steel output under different treatment year imputation for comparison plants.

Back

Output, Advanced Plants: Alternative Timing

	Output				Output		
	(1)	(2)	(3)		(1)	(2)	(3)
Adv * Year 1	0.062***	0.066***	0.070***	Adv * Year 30	0.292***	0.295***	0.299***
	(0.017)	(0.021)	(0.022)		(0.038)	(0.041)	(0.040)
Adv * Year 10	0.098***	0.105***	0.109***	Adv * Year 40	0.402***	0.411***	0.410***
	(0.029)	(0.031)	(0.033)		(0.040)	(0.039)	(0.038)
Adv * Year 20	0.180***	0.183***	0.189***				
	(0.030)	(0.034)	(0.036)				
Main Spec.	Yes	No	No	Main Spec.	Yes	No	No
Imputed Year	First	Last	Mean	Imputed Year	First	Last	Mean
Observations	12,160	12,160	12,160	Observations	12,160	12,160	12,160

Notes. Annual γ_t coefficients estimated from the equation 1 for plant logged steel output under different treatment year imputation for comparison plants.

Back

Output, Basic Plants: Alternative Clustering

	Output				
	(1)	(2)	(3)	(4)	(5)
Basic * Year 1	(0.018)	(0.017)	(0.015)	(0.014)	(0.012)
Basic * Year 10	(0.025)***	(0.022)***	(0.020)***	(0.019)***	(0.019)***
Basic * Year 20	(0.046)*	(0.045)*	(0.044)*	(0.045)*	(0.044)*
Basic * Year 30	(0.044)	(0.043)	(0.042)	(0.040)	(0.035)
Basic * Year 40	(0.043)	(0.040)	(0.039)	(0.037)	(0.035)
Cluster: Plant	Yes	No	No	No	No
Cluster: Firm	No	Yes	No	No	No
Cluster: County	No	No	Yes	No	No
Cluster: Firm-Year	No	No	No	Yes	No
Cluster: County-Year	No	No	No	No	Yes
Observations	12,160	12,160	12,160	12,160	12,160

Notes. Annual β_t coefficients clustering at different levels of aggregation.

Back

Output, Advanced Plants: Alternative Clustering

	Output				
	(1)	(2)	(3)	(4)	(5)
Adv * Year 1	(0.017)***	(0.016)***	(0.014)***	(0.013)***	(0.011)***
Adv * Year 10	(0.029)***	(0.025)***	(0.023)***	(0.020)***	(0.019)***
Adv * Year 20	(0.030)***	(0.029)***	(0.026)***	(0.024)***	(0.023)***
Adv * Year 30	(0.038)***	(0.036)***	(0.033)***	(0.030)***	(0.029)***
Adv * Year 40	(0.040)***	(0.038)***	(0.035)***	(0.033)***	(0.031)***
Cluster: Plant	Yes	No	No	No	No
Cluster: Firm	No	Yes	No	No	No
Cluster: County	No	No	Yes	No	No
Cluster: Firm-Year	No	No	No	Yes	No
Cluster: County-Year	No	No	No	No	Yes
Observations	12,160	12,160	12,160	12,160	12,160

Notes. Annual γ_t coefficients clustering at different levels of aggregation.

Back

Bounding Based on Correlation Between Observables and Unobservables

	Main Results	$\delta = 0.1$	$\delta = 0.2$	$\delta = 0.4$	$\delta = 0.6$	$\delta = 0.8$	$\delta = 1$	δ for $\beta = 0$
Basic * Year 1	0.002	0.002	0.002	0.003	0.002	0.002	0.002	
Basic * Year 5	0.113	0.109	0.108	0.105	0.103	0.101	0.099	8.34
Basic * Year 10	0.130	0.124	0.122	0.121	0.120	0.118	0.117	9.32
Basic * Year 20	0.085	0.083	0.081	0.079	0.077	0.074	0.073	9.87
Basic * Year 30	0.039	0.036	0.033	0.029	0.026	0.024	0.021	
Basic * Year 40	0.009	0.008	0.007	0.006	0.007	0.005	0.007	
Adv * Year 1	0.062	0.057	0.055	0.053	0.051	0.049	0.046	10.98
Adv * Year 5	0.089	0.087	0.085	0.082	0.079	0.075	0.071	11.77
Adv * Year 10	0.098	0.095	0.093	0.090	0.082	0.080	0.077	12.54
Adv * Year 20	0.180	0.177	0.173	0.171	0.169	0.167	0.163	14.61
Adv * Year 30	0.292	0.288	0.285	0.283	0.278	0.276	0.270	16.87
Adv * Year 40	0.402	0.398	0.395	0.392	0.390	0.387	0.381	19.12

Notes. The table shows how different hypotheses on the degree of correlation between observables and unobservables affect selected β_t and γ_t coefficients from Equation 1. The notation follows Oster (2019). The coefficient δ is the relative degree of selection on observed and unobserved variables.

Back

Output, Basic Plants: Using Clark (1995) Data

	Output			
	(1)	(2)	(3)	(4)
Basic * Year 1	0.002	0.001	0.003	0.001
	(0.018)	(0.016)	(0.015)	(0.016)
Basic * Year 10	0.130***	0.203***	0.117***	0.085***
	(0.025)	(0.028)	(0.019)	(0.022)
Basic * Year 20	0.085*	0.095*	0.079*	0.055*
	(0.046)	(0.052)	(0.045)	(0.034)
Basic * Year 30	0.039	0.045	0.033	0.021
	(0.044)	(0.049)	(0.041)	(0.033)
Specification	Main	Max	Min	Min-Max
Observations	12,160	12,160	12,160	12,160

Notes. Selected annual β_t coefficients from Equation 1, using the minimum, the maximum, or the minimum for basic and advanced plants and the maximum for comparison plants production estimates from Clark (1995).

Back

Output, Advanced Plants: Using Clark (1995) Data

	Output			
	(1)	(2)	(3)	(4)
Advanced * Year 1	0.062***	0.081***	0.055***	0.050***
	(0.017)	(0.023)	(0.016)	(0.015)
Advanced * Year 10	0.098***	0.155***	0.086***	0.079***
	(0.029)	(0.033)	(0.026)	(0.02)
Advanced * Year 20	0.180***	0.267***	0.167***	0.154***
	(0.030)	(0.044)	(0.036)	(0.027)
Advanced * Year 30	0.292***	0.309***	0.283***	0.272***
	(0.038)	(0.041)	(0.031)	(0.026)
Specification	Main	Max	Min	Min-Max
Observations	12,160	12,160	12,160	12,160

Notes. Selected annual γ_t coefficients from Equation 1, using the minimum, the maximum, or the minimum for basic and advanced plants and the maximum for comparison plants production estimates from Clark (1995).

Back