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

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Motivation

Industrialization key driver of economic development

- Economic activity moved from agriculture to industry
- $\rightarrow$ Countries grew rich (Gollin et al., 2013; Herrendorf and Schoellman, 2015; Porzio et al., 2021)
- Industrial policy used to accelerate industrialization

Big Push industrialization strategy (Rosenstein-Rodan, 1943; Murphy et al., 1989)

- Building a modern industrial sector
- Massive and simultaneous public investments in capital-intensive industries
- Often supported by technology and know-how transfers (Stokey, 2020)

Limited empirical evidence on causal and long-run implications of industrial policy

- Lack of long-term data on firm performance
- Policymakers' decision of targeted firms and industries
- Technology and knowledge transfer often occurred simultaneously

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

"156 Projects" $\rightarrow$ technologically advanced, capital-intensive industrial facilities

- Most comprehensive technology transfer in modern history (Lardy, 1995; Zhikai and Wu, 2002)
- *Technology Transfer*: Best machineries and equipment in Soviet Union
- *Know-How Transfer*: Training of Chinese engineers and high-skilled technicians

Data collection

- 139 projects approved and signed in 1950-1957
- 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

- Some already received Soviet machineries and training $\rightarrow$ *Know-how plants*
- Some others already received Soviet machineries $\rightarrow$ *Technology plants*
- No transfer, maintained Chinese capital $\rightarrow$ *Comparison plants*

Preview of the Results

Know-how transfer: Long-lasting effects; Technology transfer: faded away

- *Know-how*: + 20% after 20 years, + 49% after 40 years relative to technology plants
- *Technology*: + 12% output increase in 6 years relative to comparison plants
- No significant impact after 20 years

Technology upgrade driven by know-how transfer

- Higher quality of steel production, less scrapped output
- Development of new production processes and technologies
- More exports after 1978

Big Push: self-sustaining investments due to spillover effects (Kline and Moretti, 2013)

- *Know-How*: Higher productivity and technology upgrade in related firms
- At county-level higher level of STEM degrees and technical schools
- Since late 1990s, productivity advantage for privatized firms

Contribution to the Literature

Technology transfer in developing countries *Technology adoption*: Caselli and Coleman (2001), Comin and Hobijn (2010), de Souza (2022); *Effects on firm performance*: Pavcnik (2002), Mel et al. (2008), Goldberg et al. (2010), Bloom et al. (2013), Bruhn et al. (2018), Giorcelli (2019), Hardy and Jamie (2021); *Barriers to adoption*: Atkin et al. (2017), Bloom et al. (2020), Juhász et al. (2024)

- Complementarities between technology and know-how
- Technology transfer does not persist without know-how transfer

Role of engineers on economic development *Industrial revolution*: Mokyr, (2005); Hanlon (2022); Squicciarini and Voigtlander (2015), Maloney and Valencia Caicedo (2022), Juhász et al. (2024); *Research engineers and growth*: Romer (1990); Murphy et al. (1991)

- Foster early post-WWII industrialization
- Promote new production processes and technological upgrade

Big Push and industrial policies Rosenstein-Rodan (1943); Murphy et al. (1989), Wade, (1990), Kline and Moretti (2014), Liu (2019), Mitrunen (2020), Choi and Levchenko (2021), Kim et al. (2021), Bianchi and Giorcelli (2023), Lane (2023), Heblic et al. (2024)

- Disentangle technology from know-how transfers, tracking same plants for 40 years
- China: "the fastest sustained expansion by a major economy in history" (Morrison, 2019)

Outline

- Historical Setting
- Data
- Empirical Strategy
- Effects of Technology Transfer on Firm Outcomes
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The Chinese "Big Push" Industrialization Strategy in 1950s

Goal of People's Republic of China: building a modern industrial system (Ji, 1995)

- Lack of expertise to do so independently
- Soviet Union: Big Push development strategy in 1930s
- Centrally planned investments in heavy industry and machinery production (Allen, 2011)

Sino-Soviet Treaty of Friendship, Alliance and Mutual Assistance

- "156 Projects": technologically advanced, large-scale, capital-intensive industrial facilities
- Several agreements between 1950 and 1957
- 45% of Chinese GDP in 1949; 8% of Soviet Union GDP in 1950

"Major turning point in the course of China's modernization" (Yimin and Mingchang, 2015)

- "Largest technology transfer in human history" (Cehn and Zofka, 2022)
- "Unprecedented in scale and scope," even relative to the US Marshall Plan (Bayasgalan, 2022)
- Best technology available in Soviet Union; best in the world for steel and iron (Lardy, 1995)

Plan for Building the 156 Projects

Duplication of whole Soviet plants

- Help in selecting plant site and supervision in plant construction
- Far from coasts for defense purposes and close to natural resources
- Shaped industrialization in China

Technology transfer

- Installation of state-of-the-art machinery and equipment
- Provision of product designs, engineering designs and technical data
- “would enable China to have its own complete industrial sector” (Hirata, 2018)

Know-how transfer

- Engineers: Wide range of topics from theory to specific production practices
- Production supervisors: “scientific management” principles and quality-control methods
- High-skilled technicians: on-the-job training by Soviet experts

Location of the 156 Projects

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

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Soviet Aid in Steel Industry

Big Push core idea: industrialization based on steel industry

- 45% of total investments (Zhang et al., 2006)
- 20 industrial clusters
- Composed of 304 independent plants

Soviet Blast furnaces among the best in the world

- Comparable to Western world's ones (Clark, 1995)
- Expected to be installed in China even before some Soviet factories (Lardy, 1995)
- Know-how to operate them and organizational methods (Clark, 1973)

Chinese management impressed Indian Prime Minister Nehru (Hirata, 2018)

- Soviet Union promoted technology transfer beyond Chinese case
- "Entire process of production in the plant [was] being operated by Chinese experts"
- Americans "never allow[ed] Indians to manage the most important mechanism of the plants"

Substantial Delays in Completion of “156 Projects”

Machineries, equipment and trainers arrived or started operations later than planned

- “China demanded too much too quickly” (Zhang et al., 2006)
- In Soviet Union no enough machineries or experts
- Temporary installation of Chinese capital to start operation

Pressure to produce caused additional delays

- Accidents on the Soviet side destroyed critical equipment (Filatov, 1975)
- Too few Soviet experts to visit Chinese plants and translators (Filatov, 1980)
- Miscommunication between Soviet and Chinese experts (Kiselev, 1960)

In July 1960 Sino-Soviet Split suddenly ended technology transfer

- Due to ideological and political issues
- Stopped provision of machineries and equipment
- Overnight withdrawal of Soviet experts in China

Implications of Split for 156 Projects

By 1960 all plants had been built and were in operation

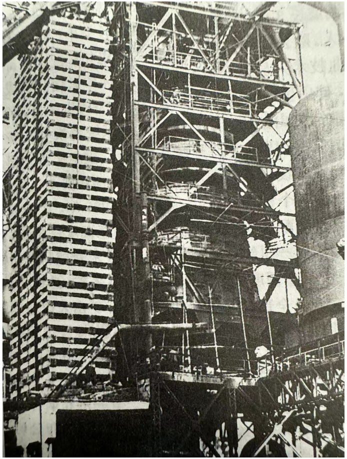
- Received Soviet capital and training $\rightarrow$ *know-how plants*
- Received only Soviet capital $\rightarrow$ *technology plants*
- No transfer, maintained with domestic technology $\rightarrow$ *comparison plants*

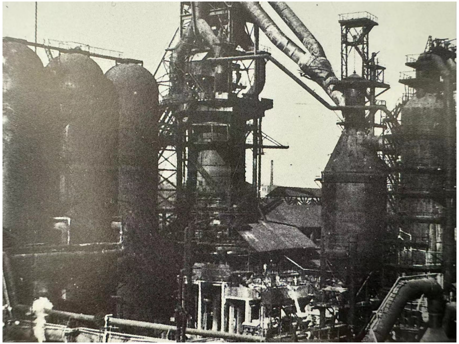
Anshan Iron and Steel Company

"Impressive modern, giant metallurgical complex, where the entire process of production in the enterprise [was] being operated by Chinese experts, [...] while in India the British and Americans never allow[ed] Indians to manage the most important mechanism of the enterprises"

Clark (1973)

Large-Scale Blast Furnace Knows as “Glorious Furnace” in Anshan





Notes: Construction of the “Glorious Furnace” at the Anshan Iron and Steel Company. *Source*: The Memoir of Workers at Ansteel.

On-the-Job Training Provided by Soviet Engineers

Notes: Arrival of the Soviet engineer Maximoff at the Anshan Iron and Steel Company (left) and Soviet electrical engineer Zhuowugnodny explaining Anshan high-skilled technicians how to use the blast furnace (right). *Source*: The Memoir of Workers at Ansteel.

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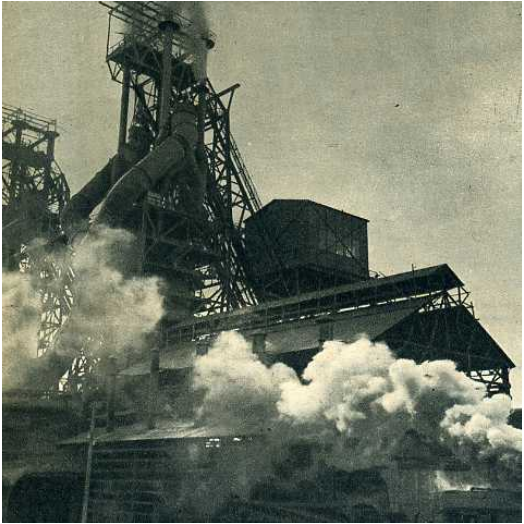
Wuhan Iron and Steel Corporation

"Surprising state-of-the-art massive metallurgical facilities [...] whose workers were copying Soviet designs and products without thinking. As a consequence, the resulting products had many flaws and the scrapped output was enormous"

Clark (1973)

Large-Scale Blast Furnace Knows as “Glorious Furnace” in Wuhan



Notes: First large-scale blast furnace in Wuhan Iron and Steel Corporation, using Kolesnikov’s combined operating methods that only took 6 and a half hours to produce the steel. *Source*: Ji (2019)

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Chengde Iron and Steel Company

"Impressive size for the eyes from a distance and apparently brand-new, but, as one walks in, production capital is a mixture of that of a Japanese and a Soviet factory of the 1930s"

Clark (1973)

Chengde Iron and Steel Company

Notes: View of the Chengde Iron and Steel Company. *Source*: Ji (2019)

State-Owned Enterprise Incentives in a Command Economy

- China was a command economy (1949–early 1980s)
  - All factories state-owned; production centrally planned
  - Government set output targets, allocated inputs, fixed prices
  - Firms maximized output to meet quotas, not profits
- Non-quantity performance indicators introduced
  - From 1952: profits, product quality, cost reduction added
  - "Quality first" (1960s): downstream firms could reject faulty goods
  - Retained profits (7–16%) funded bonuses and upgrades
- Plants had limited autonomy (planning weaker than in the USSR)
  - Some influence over input quotas; extra-plan exchanges tolerated
  - 5–30% of the product mix could be sold independently
  - Still subordinate to hierarchy; had to meet state targets

Outline

- Historical Setting
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- Conclusions

Data Collection

156 projects from *National Archives Administration of China*

- 139 clusters: name, industry, firm location, starting dates, size, capacity, # workers
- Transfer(s) eventually received
- 304 steel plants: 98 technology+know-how, 91 technology, 115 no transfers

Plant-level data for steel industry

- *Steel Association Reports* (1949-2000)
- Product quantities, quality, workers, production processes
- Complemented with technology adoption from *Ministry of Industry*

All industries

- *Second Industrial Survey* (1985)
- *China Industrial Enterprises* database (1998-2013)
- Firm output, capital investment, employees, profits, fixed investments, exports

Summary Statistics for the 156 Projects

	Mean (1)	SD (2)	Min (3)	Max (4)
Approval Year	1953.42	1.48	1952	1957
Start Year	1955.22	1.11	1953	1958
Expected Physical Capital Delivery Year	1957.87	3.06	1954	1963
Expected Soviet Experts Arrival Year	1958.62	2.77	1955	1963
Planned Investment (m)	580.34	224.14	80.03	3,232.81
Expected Equipment Value (m)	259.35	49.76	48.79	1,340.55
Number of Workers (k)	39.91	14.1	25.8	70.61
Number of Plants	8.69	1.57	2	22
Expected Length	5.64	1.39	3	9
Observations	139	139	139	139

Notes. *Approval* and *Start Year* are approval and start year; *Expected Delivery/Arrival Years* are Soviet physical capital and experts expected arrival; *Planned Investment* and *Equipment Value* are measured in 2020 US$ millions; *Number of Workers(k)* is thousand number of employees; *Number of Plants* is number of plants; *Expected Length* is expected duration.
Source: National Archives Administration of China.

▸ Steel Industry

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Data Manipulation and Cross-Check

Measurement shortcomings in officially-released command-economies' data

- Variation in quality and methods used
- Systematic misreporting or data falsification
- Managers' incentives to inflate output

Steel Association Reports intended for internal use

- Output manipulation? 304 plants exceeded quotas
- Cross-check: peer monitoring and supply chain
- Split: if any manipulation, in favor of comparison plants

Alternative measures

- Technologies in use and production processes
- Cross-check with Anshan own production data
- Cross-check with Clark (1995) $\rightarrow$ Steel Annual Reports are accurate

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Empirical Specification

$$\text{outcome}_{it} = \alpha_i + \theta_t + \sum_{\tau=-5}^{40} \beta_\tau \cdot (\text{Physical Capital}_i \cdot \text{Years after Transfer=}\tau_{it}) + \sum_{\tau=-5}^{40} \gamma_\tau \cdot (\text{Know-How}_i \cdot \text{Years after Transfer=}\tau_{it}) + \epsilon_{it}$$

- Outcome$_{it}$: logged output and TFP of plant *i* at time *t*
- Physical Capital$_i$: indicator for plants that received Soviet physical capital transfer
- Know-How$_i$: indicator for plants that also received Soviet know-how transfer
- Years after Treatment=τ_{it}: τ calendar years before/after plant *i* got Soviet transfer
  - Assumed to be 1960 for comparison plants; excluded year $\tau = -1$
- α_i: plant fixed effects; θ_t: year fixed effects
- Standard errors block-bootstrapped at the industrial-cluster level (1,000 replications)

Identification Assumptions

304 steel plants on the same trend in the absence of Soviet interventions

- β_t measures the effects on plant performance of a technology transfer relative to no transfer
- γ_t measures the additional effect of a know-how transfer on top of a technology transfer

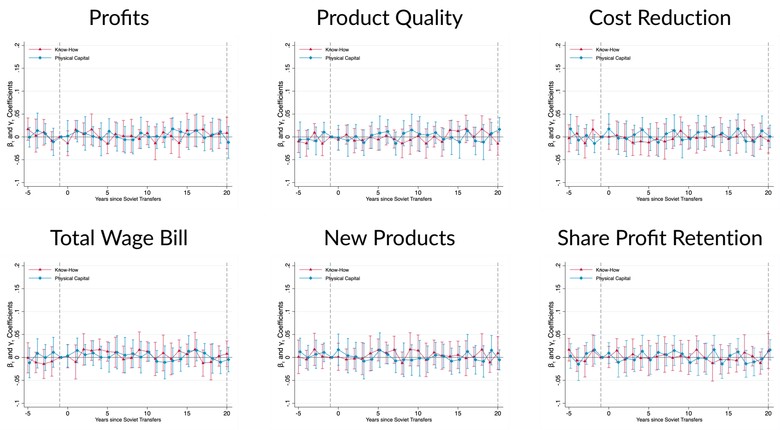
Supportive empirical evidence

- Are the outcomes comparable for the 304 plants?
- Tests for pre-trends in plant performance
- Balancing test of plants' characteristics and outcomes
- Balancing test of clusters' and counties' characteristics

Reallocation of resources across 304 plants after Split?

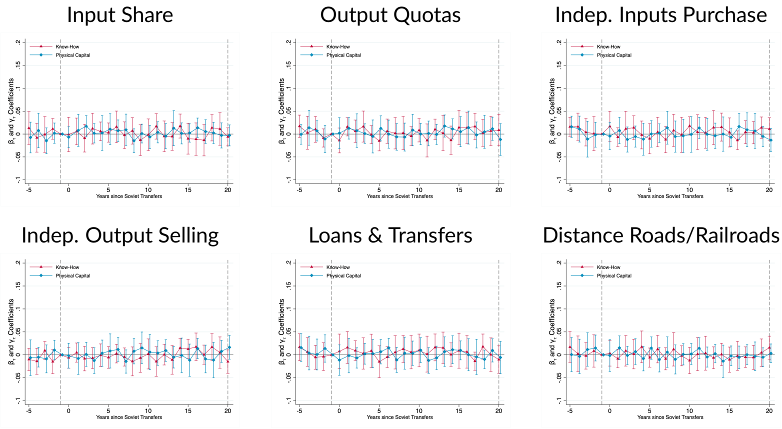
- Unlikely from treated to comparison plants
- From comparison to treated plants
- China could industrialize without technology transfer (Zhang et al., 2006)
- No differences in quotas, transfers, access to infrastructure, exposure to historical events

Are the Outcomes Comparable? Same Incentives



Notes. Annual β_τ (physical capital) and γ_τ (know-how) coefficients from Equation 1 for whether a plant pursued each key performance indicator, and for the share of profit retention. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications. *Source*: Steel Association Reports (1949–2000).

Are the Outcomes Comparable? Comparable Manager Autonomy



Notes. Annual β_τ (physical capital) and γ_τ (know-how) coefficients from Equation 1 for managerial autonomy (inputs/outputs) and government support. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications. *Source*: Steel Association Reports (1949–2000).

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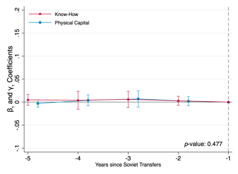
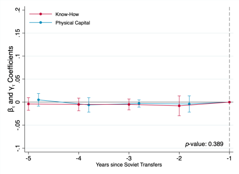
No Differential Pre-Trends

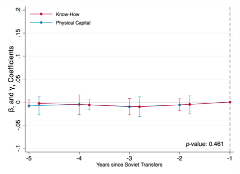
Output



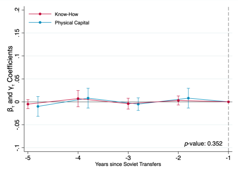
TFPQ



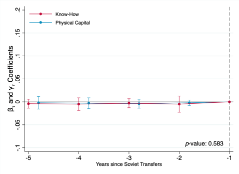
Crude Steel



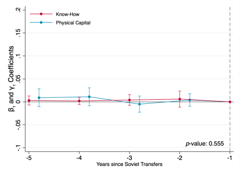
Pig Iron



Capital Stock



Employment



Notes. Pre-Soviet-intervention β_τ (physical capital) and γ_τ (know-how) coefficients from Equation 1, in the five years before the transfer: small, never individually significant, and jointly zero (F-test), confirming common pre-trends. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications. *Source*: Steel Association Reports (1949–2000).

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No Differences in Soviet Transfers at time t=-1

	Know-How + Capital (1)	Capital (2)	No Transfer (3)	1 vs 2 (4)	2 vs 3 (5)	All (6)
Expected Equipment Value (m)	188.67	190.23	193.18	0.506	0.496	0.572
	(206.41)	(207.96)	(210.44)			
Expected Arrival of Capital	1957.31	1957.44	1957.08	0.731	0.610	0.581
	(3.45)	(3.59)	(3.12)			
Expected Arrival of Experts	1958.56	1958.78	1958.21	0.689	0.572	0.532
	(2.96)	(2.71)	(2.88)			
Share of Existing Plants	0.08	0.09	0.12	0.646	0.661	0.615
	(0.12)	(0.11)	(0.15)			
Distance Coal Deposits (km)	5.77	6.03	5.82	0.663	0.560	0.549
	(2.58)	(2.41)	(2.98)			
Distance Coke Deposits (km)	7.59	7.68	7.21	0.504	0.556	0.499
	(3.48)	(3.87)	(3.09)			
Observations	98	91	115	189	206	304

Notes. Columns 1–3 report mean and standard deviation (in parentheses); columns 4–6 report p-values of mean-equality tests (1 vs 2, 2 vs 3, and jointly across all three). *Source*: Steel Association Reports (1949–2000).

No Differences in Production and Productivity at time t=-1

	Know-How + Capital (1)	Capital (2)	No Transfer (3)	1 vs 2 (4)	2 vs 3 (5)	All (6)
Output (m tons)	602.06	604.24	602.85	0.689	0.623	0.655
	(19.43)	(18.67)	(23.67)			
Productivity (log TFPQ)	1.21	1.28	1.25	0.578	0.651	0.678
	(0.32)	(0.55)	(0.25)			
Crude Steel (m tons)	153.49	152.82	154.62	0.569	0.486	0.642
	(13.98)	(14.18)	(14.23)			
Pig Iron (m tons)	96.08	101.04	99.31	0.254	0.761	0.555
	(15.18)	(15.70)	(15.12)			
Observations	98	91	115	189	206	304

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No Differences in Capital and Employment at time t=-1

	Know-How + Capital (1)	Capital (2)	No Transfer (3)	1 vs 2 (4)	2 vs 3 (5)	All (6)
Capital Stock (m)	57.92	58.18	58.40	0.608	0.624	0.516
	(8.04)	(7.81)	(7.54)			
Employees (k)	3.49	3.60	3.44	0.453	0.532	0.492
	(1.03)	(0.72)	(0.83)			
Engineers (k)	0.38	0.36	0.37	0.801	0.853	0.827
	(0.04)	(0.05)	(0.05)			
High-Skilled Technicians (k)	0.51	0.57	0.52	0.497	0.563	0.647
	(0.14)	(0.36)	(0.33)			
Unskilled Workers (k)	2.60	2.64	2.62	0.578	0.489	0.542
	(1.05)	(0.75)	(0.91)			
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No Differences in Distance from Borders and Infrastructure

	Know-How + Capital	Capital	No Transfer	1 vs 2	2 vs 3	All
	(1)	(2)	(3)	(4)	(5)	(6)
Distance Border (km)	231.60	230.44	229.45	0.510	0.616	0.552
	(61.34)	(62.15)	(65.74)			
Distance Province (km)	67.32	68.25	68.18	0.526	0.488	0.582
	(17.89)	(16.58)	(18.01)			
Distance Coast (km)	515.64	517.76	514.28	0.683	0.537	0.562
	(54.39)	(58.71)	(56.32)			
Distance Treated Ports (km)	581.30	582.83	580.93	0.706	0.762	0.609
	(41.32)	(43.98)	(42.72)			
Distance Highway (km)	38.11	37.65	38.42	0.526	0.711	0.654
	(12.43)	(11.57)	(13.42)			
Distance Railway (km)	63.49	62.55	62.31	0.572	0.521	0.522
	(21.19)	(22.40)	(19.87)			
Observations	98	91	115	189	206	304

Notes. Balancing tests on the geographical characteristics of the 304 steel plants. Columns 1–3 report mean and standard deviation (in parentheses); columns 4–6 report p-values of mean-equality tests (1 vs 2, 2 vs 3, and jointly across all three). *Source*: Steel Association Reports (1949–2000).

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No Differences in Clusters' Characteristics

	Physical Capital (1)	Know-How (2)	*p*-value (3)		Physical Capital (1)	Know-How (2)	*p*-value (3)
Approval Year	0.012	-0.008	0.608	Planned Investment (m)	-0.019	0.011	0.861
	(0.010)	(0.011)			(0.023)	(0.015)	
Start Year	-0.015	0.003	0.767	Actual Investment (m)	0.011	-0.005	0.619
	(0.018)	(0.006)			(0.013)	(0.007)	
Expected Length	0.003	0.002	0.538	Exp. Equipment Value (m)	0.013	-0.006	0.561
	(0.004)	(0.005)			(0.016)	(0.009)	
Exp. Capital Delivery Year	0.005	-0.004	0.426	Number of Workers (k)	-0.009	0.010	0.667
	(0.007)	(0.006)			(0.010)	(0.012)	
Exp. Experts Arrival Year	-0.007	0.003	0.552	Number of Plants	-0.008	0.005	0.522
	(0.010)	(0.005)			(0.010)	(0.007)	
Observations	304	304	304		304	304	304

Notes. Coefficients from regressing the characteristics of the project each plant belonged to on an indicator for plants that received the Soviet physical capital transfer and an indicator for plants that also received the know-how transfer. Data are provided at the project level from the National Archives Administration of China. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications. Column 3 reports the *p*-value of testing jointly equality of the coefficients to zero.

No Differences in Hosting Counties in 1953

	Technology (1)	Know-How (2)	*p*-value (3)
Log Total Firms	0.018	-0.013	0.556
	(0.013)	(0.011)	
Log Population	-0.015	0.012	0.743
	(0.016)	(0.013)	
Employment Share	0.006	0.003	0.691
	(0.014)	(0.006)	
Log Gvt. Funds	0.004	0.007	0.701
	(0.011)	(0.012)	
Observations	304	304	304

Notes. *Log total firms* is logged total number of firms; *Log population* is logged total population; *Employment Share* is the fraction of employed population over total population; *Log Gvt. Funds* is government transfers. Standard errors are clustered at the county level. Column 3 reports the *p*-value of testing jointly equality of the coefficients to zero. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Identification Assumptions

Transfer eventually received orthogonal to project characteristics or potential success

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

Supportive empirical evidence

- Tests for pre-trends in plant performance
- Balancing test of plants' characteristics and outcomes
- Balancing test of clusters' and counties' characteristics

Reallocation of resources across 304 plants after Split?

- Unlikely from treated to comparison plants
- From comparison to treated plants
- China could industrialize without technology transfer (Zhang et al., 2006)
- No differences in quotas, transfers, access to infrastructure, exposure to historical events

Outline

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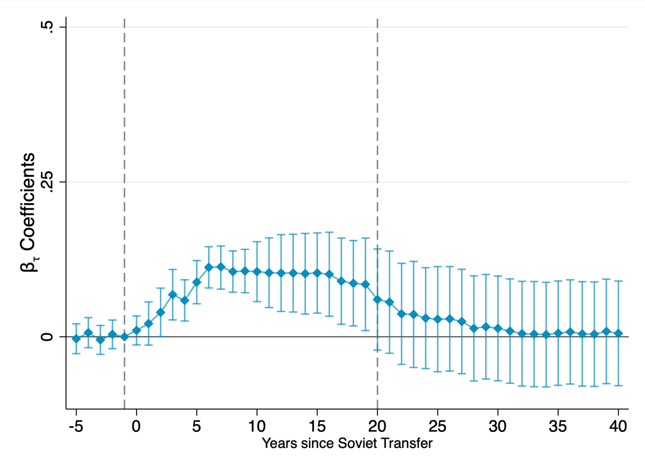
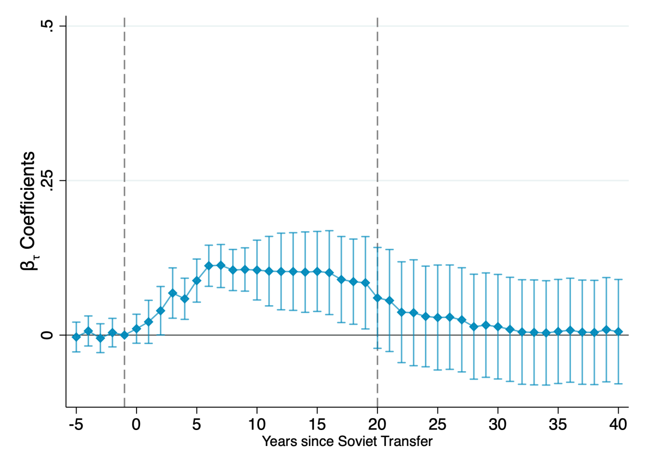
Plant Output: +12% in 6 Years in Technology vs Comparison Plants



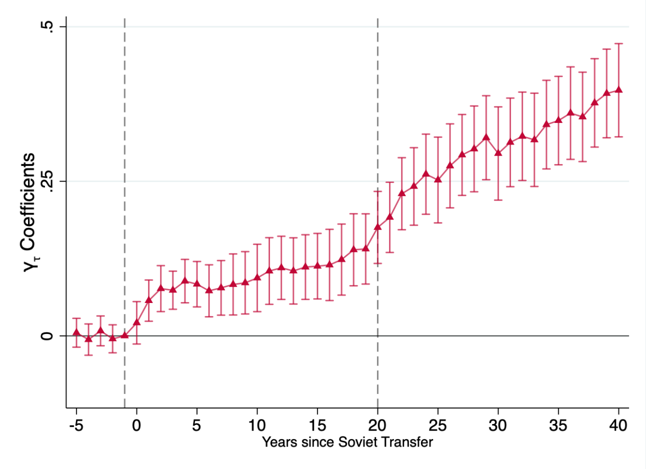
Notes. Annual β_t coefficients estimated from the equation 1 for plant output, measured in logged m tons of steel. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications. *Source*: Steel Association Reports (1949–2000).

Plant Output: No Significant Effects after 20 Years



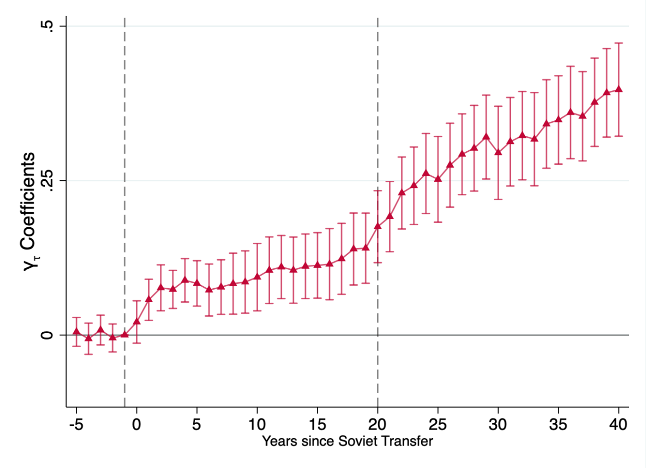
Notes. Annual β_t coefficients estimated from the equation 1 for plant output, measured in logged m tons of steel. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications. *Source*: Steel Association Reports (1949–2000).

Plant Output: +19% in 20 Years for Know-How vs Tech. Plants



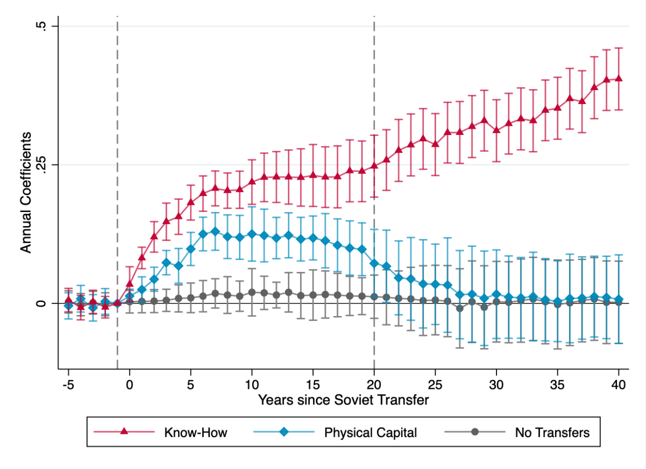
Notes. Annual γ_t coefficients estimated from the equation 1 for plant output, measured in logged m tons of steel. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications. *Source*: Steel Association Reports (1949–2000).

Plant Output: +49% in 40 Years for Know-How vs Tech. Plants



Notes. Annual γ_t coefficients estimated from the equation 1 for plant output, measured in logged m tons of steel. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications. *Source*: Steel Association Reports (1949–2000).

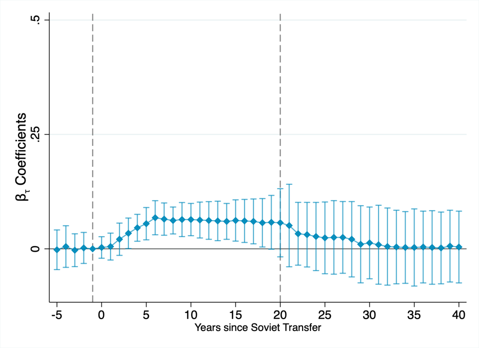
Effects on Driven by Technology and Know-How Plants

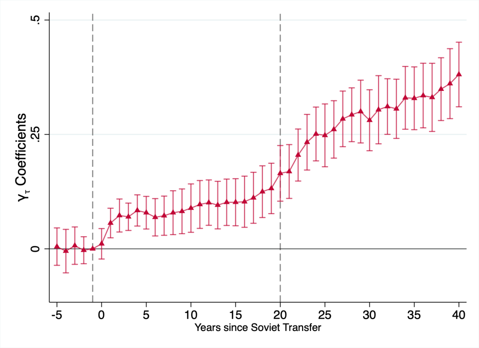


Notes. Single differences estimated from the equation 1 for plant output, measured in logged m tons of steel. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications. *Source*: Steel Association Reports (1949–2000).

▸ Comparison Plants

Comparable Effects in Productivity Increases





Notes. Annual β_t coefficients estimated from the equation 1 for plant TFP, computed as the residuals of OLS regression of plant logged physical output on logged workers, capital stock and inputs, and plant and year fixed effects. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications. *Source*: Steel Association Reports (1949–2000).

Ruling Out Alternative Explanations

Japanese Legacy in Manchuria ▸ Results

Political Connections ▸ Results

Great Leap Forward ▸ Results

Third Front Movement ▸ Results

Cultural Revolution ▸ Results

Effects in 1985 and in 1998-2013 ▸ Results

Robustness Checks

Alternative Fixed Effects & Estimators ▸ Results

Alternative Clustering ▸ Results

Using US prices ▸ Results

Alternative TFP Estimations ▸ Results

Outline

- Historical Setting
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Firm Upgrading

Results consistent with capital-skill complementarities (Griliches, 1969; Krusell et al., 2000)

- Technologically-advanced capital goods complementary to skilled workers
- Skilled workers instrumental in firm upgrading
- Greater availability of both $\rightarrow$ quality and technology upgrade

Three empirical tests

- Quality of steel product (Verhoogen, 2023)
- Technology upgrade (Verhoogen, 2023)
- Human capital (Goldin and Ktaz, 1998)

Trade after 1978

- China began gradually opening to international trade
- Further increase of know-how transfer effects
- Analysis of technology import contracts

Increased Quality Production in Know-How Plants

	Crude Steel	Pig Iron	Scrapped Output
Know-How * Year 1	0.004	-0.032	0.005
	(0.035)	(0.030)	(0.007)
Know-How * Year 5	0.055***	-0.048***	-0.075***
	(0.015)	(0.012)	(0.012)
Know-How * Year 10	0.178***	-0.138***	-0.151***
	(0.046)	(0.044)	(0.045)
Know-How * Year 20	0.209***	-0.189***	-0.178***
	(0.049)	(0.048)	(0.043)
Observations	7,904	7,904	7,904

Notes. Selected annual β_τ coefficients and γ_τ coefficients. *Source*: Steel Association Reports (1949–2000). *Crude Steel*, *Pig Iron* and *Scrapped Output* are logged million tons of crude steel, pig iron and output scrapped due to low quality. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Limited and Short-Live Quality Improvements in Technology Plants

	Crude Steel	Pig Iron	Scrapped Output
Physical Capital * Year 1	0.011	-0.018	0.002
	(0.011)	(0.020)	(0.004)
Physical Capital * Year 5	0.112**	-0.106***	0.005
	(0.051)	(0.047)	(0.006)
Physical Capital * Year 10	0.082**	-0.076*	0.010
	(0.044)	(0.041)	(0.014)
Physical Capital * Year 20	0.021	-0.028	0.008
	(0.047)	(0.049)	(0.009)
Observations	7,904	7,904	7,904

Notes. Selected annual β_τ coefficients and γ_τ coefficients. *Source*: Steel Association Reports (1949–2000). *Crude Steel*, *Pig Iron* and *Scrapped Output* are logged million tons of crude steel, pig iron and output scrapped due to low quality. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Technological Upgrade in Know-How Plants

	Converters	Casting	High-Skilled	Unskilled
Know-How * Year 1	0.003	0.008	0.004	0.005
	(0.010)	(0.011)	(0.006)	(0.008)
Know-How * Year 5	0.252***	0.019	0.026***	-0.025***
	(0.041)	(0.013)	(0.007)	(0.004)
Know-How * Year 10	0.345***	0.267***	0.053***	-0.060***
	(0.053)	(0.051)	(0.007)	(0.007)
Know-How * Year 20	0.651***	0.784***	0.068***	-0.071***
	(0.151)	(0.143)	(0.007)	(0.006)
Observations	7,904	7,904	7,904	7,904

Notes. Selected annual β_τ coefficients and γ_τ coefficients. *Source*: Steel Association Reports (1949–2000). *Converters* and *Casting* are indicators for plants using the basic oxygen converters and the continuous casting furnaces. *High-Skilled* and *Unskilled* are logged thousands of engineers and production supervisors, and unskilled employees. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

No Effects in Technology Plants

	Converters	Casting	High-Skilled	Unskilled
Physical Capital * Year 1	0.006	0.005	0.002	-0.003
	(0.005)	(0.009)	(0.003)	(0.005)
Physical Capital * Year 5	0.009	0.007	0.005	0.003
	(0.010)	(0.008)	(0.006)	(0.005)
Physical Capital * Year 10	0.009	0.006	0.013	0.015
	(0.010)	(0.008)	(0.015)	(0.020)
Physical Capital * Year 20	0.007	0.010	0.011	0.011
	(0.009)	(0.014)	(0.013)	(0.010)
Observations	7,904	7,904	7,904	7,904

Notes. Selected annual β_τ coefficients and γ_τ coefficients. *Source*: Steel Association Reports (1949–2000). *Converters* and *Casting* are indicators for plants using the basic oxygen converters and the continuous casting furnaces. *High-Skilled* and *Unskilled* are logged thousands of engineers and production supervisors, and unskilled employees. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Hiring of Better Human Capital in Know-How Plants

	Converters	Casting	High-Skilled	Unskilled
Know-How * Year 1	0.003	0.008	0.004	0.005
	(0.010)	(0.011)	(0.006)	(0.008)
Know-How * Year 5	0.252***	0.019	0.026***	-0.025***
	(0.041)	(0.013)	(0.007)	(0.004)
Know-How * Year 10	0.345***	0.267***	0.053***	-0.060***
	(0.053)	(0.051)	(0.007)	(0.007)
Know-How * Year 20	0.651***	0.784***	0.068***	-0.071***
	(0.151)	(0.143)	(0.007)	(0.006)
Observations	7,904	7,904	7,904	7,904

Notes. Selected annual β_τ coefficients and γ_τ coefficients. *Source*: Steel Association Reports (1949–2000). *Converters* and *Casting* are indicators for plants using the basic oxygen converters and the continuous casting furnaces. *High-Skilled* and *Unskilled* are logged thousands of engineers and production supervisors, and unskilled employees. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications *** p < 0.01, ** p < 0.05, * p < 0.1.

No Effects in Technology Plants

	Converters	Casting	High-Skilled	Unskilled
Physical Capital * Year 1	0.006	0.005	0.002	-0.003
	(0.005)	(0.009)	(0.003)	(0.005)
Physical Capital * Year 5	0.009	0.007	0.005	0.003
	(0.010)	(0.008)	(0.006)	(0.005)
Physical Capital * Year 10	0.009	0.006	0.013	0.015
	(0.010)	(0.008)	(0.015)	(0.020)
Physical Capital * Year 20	0.007	0.010	0.011	0.011
	(0.009)	(0.014)	(0.013)	(0.010)
Observations	7,904	7,904	7,904	7,904

Notes. Selected annual β_τ coefficients and γ_τ coefficients. *Source*: Steel Association Reports (1949–2000). *Converters* and *Casting* are indicators for plants using the basic oxygen converters and the continuous casting furnaces. *High-Skilled* and *Unskilled* are logged thousands of engineers and production supervisors, and unskilled employees. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Import of *Complementary* Equipment and More Exports after 1978

	Subs. Capital	Compl. Equipment	Log Exports	Log Int. Stand.
Physical Capital * Post 1978	0.012	0.013	0.014	0.010
	(0.009)	(0.010)	(0.018)	(0.012)
Know-How * Post 1978	-0.159***	0.186***	0.292***	0.278***
	(0.048)	(0.051)	(0.041)	(0.043)
Observations	9,120	9,120	9,120	9,120

Notes. *Post 1978* is an indicator for years after 1978. *Substitute Capital*, *Complementary Equipment*, *Exports* and *Int. St.* are logged values of foreign imported capital used to replace Soviet one, foreign equipment complementary with plant physical capital, exports, and quantity of steel that meet international standards. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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Big Push and Spillover Effects

Spillover effects at core of Big Push theory (Griliches, 1969; Krusell et al., 2000)

- Initial investments can become self-sustaining
- By stimulating complementary industries
- Due to backward and forward linkages

Did 304 plants generated spillover effects?

- 684 complementary plants not eligible for Soviet transfer
- Construct linkages with input-output matrix
- Empirical specification

$$\begin{aligned}\text{outcome}_{jit} = {} & \alpha \cdot \text{Physical Capital}_i + \beta \cdot (\text{Physical Capital}_i \cdot \text{Post Transfer}_{it}) \\ & + \gamma \cdot \text{Know-How}_i + \delta \cdot (\text{Know-How}_i \cdot \text{Post Transfer}_{it}) + \theta_t + \nu_{jit}\end{aligned}$$

- Outcome_{it}: production, productivity, tech adaption and export of plant *j* related to plant *i* at time *t*
- $\text{Physical Capital}_i/\text{Know-How}_i$: indicators if plant *i* received Soviet capital/know-how

More Output in Plants Related to Technology Plants

	Output	TFPQ	Tech. Upgrade	Sub. Capital	Com. Equipment	Exports
Physical Capital	-0.008	-0.009	0.003	0.006	0.005	0.009
	(0.015)	(0.014)	(0.005)	(0.011)	(0.008)	(0.012)
Know-How	0.006	0.005	0.006	-0.088***	0.077***	0.164***
	(0.010)	(0.011)	(0.008)	(0.021)	(0.019)	(0.035)
Phys. Capital * Post	0.095***	0.012	0.009			
	(0.028)	(0.014)	(0.010)			
Know-How * Post	0.185***	0.176***	0.322***			
	(0.035)	(0.033)	(0.106)			
Observations	27,360	27,360	27,360	13,680	13,680	13,680

Notes. *Output* is logged in million tons of steel. *TFPQ* is logged total factor productivity quantity, computed with Gandi et al. (2020)'s method. *Tech. Upgrade* is an indicator for plants that adopt a new technology. *Substitute Capital*, *Complementary Equipment* and *Exports* are logged values of foreign substitute capital, foreign complementary equipment, and exports. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

▸ STEM Human Capital ▸ Privatizations ▸ County-Level Results

More Productivity and Tech. Adoption with Know-How Plants

	Output	TFPQ	Tech. Upgrade	Sub. Capital	Com. Equipment	Exports
Physical Capital	-0.008	-0.009	0.003	0.006	0.005	0.009
	(0.015)	(0.014)	(0.005)	(0.011)	(0.008)	(0.012)
Know-How	0.006	0.005	0.006	-0.088***	0.077***	0.164***
	(0.010)	(0.011)	(0.008)	(0.021)	(0.019)	(0.035)
Phys. Capital * Post	0.095***	0.012	0.009			
	(0.028)	(0.014)	(0.010)			
Know-How * Post	0.185***	0.176***	0.322***			
	(0.035)	(0.033)	(0.106)			
Observations	27,360	27,360	27,360	13,680	13,680	13,680

Notes. *Output* is logged in million tons of steel. *TFPQ* is logged total factor productivity quantity, computed with Gandi et al. (2020)'s method. *Tech. Upgrade* is an indicator for plants that adopt a new technology. *Substitute Capital*, *Complementary Equipment* and *Exports* are logged values of foreign substitute capital, foreign complementary equipment, and exports. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

▸ STEM Human Capital ▸ Privatizations ▸ County-Level Results

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Conclusions

Effects of knowledge and technology transfers on early industrial development

- Persistent effects of combined 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

Summary Statistics for the 20 Steel Industrial Clusters

	Mean (1)	SD (2)	Min (3)	Max (4)
Approval Year	1953.67	1.56	1952	1957
Start Year	1955.41	0.69	1952	1957
Expected Physical Capital Delivery Year	1957.26	2.96	1954	1963
Expected Soviet Experts Arrival Year	1958.49	2.85	1955	1963
Planned Investment (m)	746.89	361.29	167.28	3,232.81
Expected Equipment Value (m)	469.39	36.78	103.71	1,340.55
Number of Workers (k)	46.67	11.38	31.29	70.61
Number of Plants	15.20	1.33	6	22
Expected Length	6.12	0.72	5	9
Observations	20	20	20	20

Notes. *Approval* and *Start Year* are approval and start year; *Expected Delivery/Arrival Years* are Soviet physical capital and experts expected arrival; *Planned Investment* and *Equipment Value* are measured in 2020 US$ millions; *Number of Workers(k)* is thousand number of employees; *Number of Plants* is number of plants; *Expected Length* is expected duration.
Source: National Archives Administration of China. Back

Comparison Plants vs Other Steel Plants

	Log Output	Log TFP		Log Output	Log TFP
	(1)	(2)		(1)	(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 total factor productivity quantity, computed as the residuals of OLS regression of plant logged physical output on logged workers, capital stock and inputs, and plant and year fixed effects. *Source*: Steel Association Reports (1949–2000). Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications.

◂ Back ◂ Back

Ruling Out Alternative Explanations: Government Transfers

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

Notes. *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 block-bootstrapped at the industrial cluster level with 1,000 replications.

Back

Ruling Out Alternative Explanations: Accessibility

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

Notes. *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 block-bootstrapped at the industrial cluster level with 1,000 replications.

Back

Ruling Out Alternative Explanations: Japanese Legacy in Manchuria

30 plants sat on pre-existing Japanese-era sites in Manchuria (1930s)

- Most Japanese machinery removed after WWII
- Not more likely to receive Soviet transfers (balancing tests)
- Concern: Soviet transfers interacting with preexisting Japanese expertise

Robustness checks

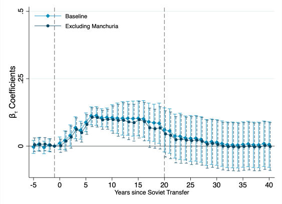
- Excluding the entire Manchuria region $\rightarrow$ results comparable to baseline
- Restricting to plants treated after 1953 (Japanese engineers gone) $\rightarrow$ unchanged
- Japanese engineers were barred from Soviet machinery (espionage fears)

$\Rightarrow$ The Japanese legacy in Manchuria does not drive the results

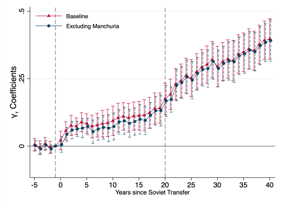
Back

Japanese Legacy in Manchuria: Excluding Manchuria

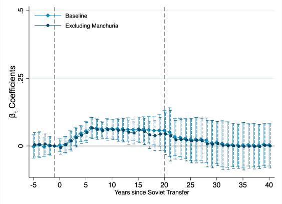
Output: Technology



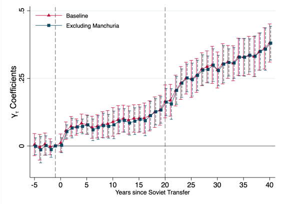
Output: Know-How



TFP: Technology



TFP: Know-How

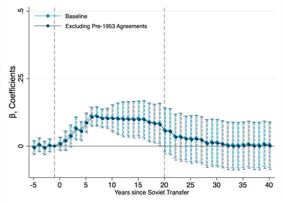


Notes. Annual β_τ (physical capital) and γ_τ (know-how) coefficients from Equation 1, excluding the entire Manchuria region. Baseline (plant and year FE) shown for reference. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications.

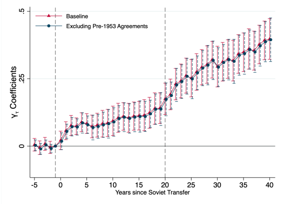
Back

Japanese Legacy in Manchuria: Excluding Pre-1953 Agreements

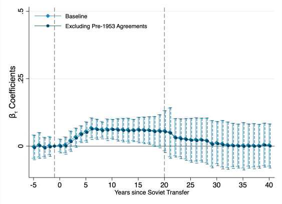
Output: Technology



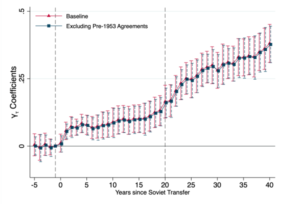
Output: Know-How



TFP: Technology



TFP: Know-How



Notes. Annual β_τ (physical capital) and γ_τ (know-how) coefficients from Equation 1, restricting to plants earmarked to receive Soviet assistance after 1953. Baseline (plant and year FE) shown for reference. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications.

Back

Ruling Out Alternative Explanations: Political Connections

Concern: transfer plants may have been more politically connected

- Or perhaps better politicians allocated to their prefectures?
- Data: biographies of Party secretaries and prefecture mayors (1949–2018)

Tests

- No differences in bureaucrats' rotations or length of terms
- No differences in politicians' education or prior experience

$\Rightarrow$ Political connections and politician quality remained comparable across prefectures

Back

Ruling Out Alternative Explanations: Political Connections

	Secretaries			Mayors		
	Born City	Uni. City	Years Edu.	Born City	Uni. City	Years Edu.
Technology * 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)
Technology * 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)
Technology * 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)
Know-How * 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)
Know-How * 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)
Know-How * 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. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications. Back

Exposure to Other Historical Events: Great Famine

	Great Famine Deaths (1)	Investments during TF Years (2)
Technology	-0.019	-0.011
	(0.025)	(0.044)
Know-How	-0.022	0.009
	(0.023)	(0.011)
Prefecture-Year FE	Yes	Yes
Observations	1,296	1,296

Notes. *Technology/Know-How* is 1 for counties where technology/know-how plants are located. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications. ***p<0.01, **p<0.05, *p<0.1. Back

Exposure to Other Historical Events: Third Front

	Great Famine Deaths (1)	Investments during TF Years (2)
Technology	-0.019	-0.011
	(0.025)	(0.044)
Know-How	-0.022	0.009
	(0.023)	(0.011)
Prefecture-Year FE	Yes	Yes
Observations	1,296	1,296

Notes. *Technology/Know-How* is 1 for counties where technology/know-how plants are located. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications. ***p<0.01, **p<0.05, *p<0.1. Back

Exposure to Other Historical Events: Cultural Revolution

Cultural Revolution (1966-1976)

- Purging any remnants of capitalism
- Caused the imprisonment of a large fraction of high-skilled workers
- Closure of schools and universities

Decline in aggregate steel production

- 304 plants almost untouched
- Too important for Chinese economy
- No deportation of high-skilled workers

Anshan Iron and Steel Company

"Cultural Revolution's radical political campaigns were reconciled with the goals of industrial production, ensuring a continuity in the steel production"

Hirata (2018)

Back

Results in 1985 and 1998-2013

	Log Value Added		Log Workers		Log TFPR	
	(1)	(2)	(3)	(4)	(5)	(6)
Technology	0.047	0.008	0.006	0.008	0.038	0.006
	(0.043)	(0.010)	(0.008)	(0.016)	(0.023)	(0.011)
Combined	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

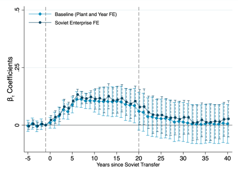
Notes. *Source*: Second Annual Survey (1985) and China Industrial Enterprises database (1998–2013). *Log Value Added* is measured in 2020 US$ millions; *Log Workers* is log k employees; *Log TFPR* is logged total factor productivity revenue computed with the Gandhi et al. (2020)'s method. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications. ***p<0.01, **p<0.05, *p<0.1.

Back

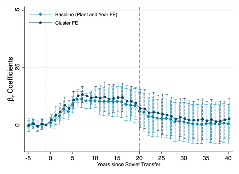
Alternative Fixed Effects: Output

Technology

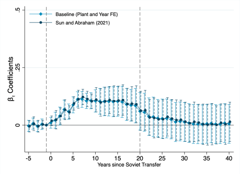
Soviet Enterprise FE



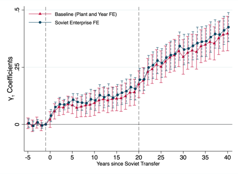
Industrial Cluster FE

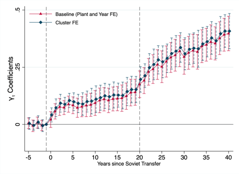


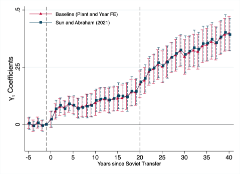
Sun and Abraham



Know-How







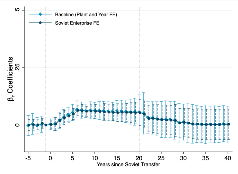
Notes. Annual β_τ (Technology) and γ_τ (Know-How) coefficients from Equation 1 for plant *output*, under alternative fixed effects and the Sun and Abraham (2021) estimator. Baseline (plant and year FE) shown for reference. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications.

◂ Back

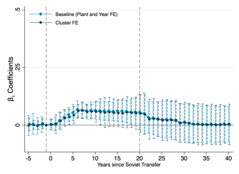
Alternative Fixed Effects: TFP

Technology

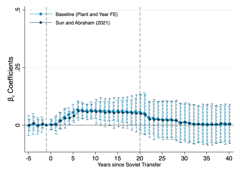
Soviet Enterprise FE



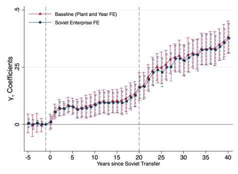
Industrial Cluster FE

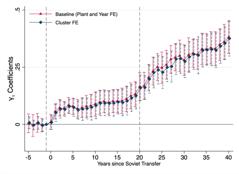


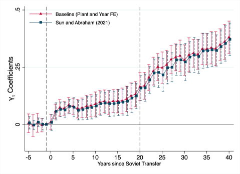
Sun and Abraham



Know-How







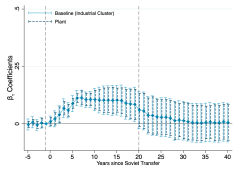
Notes. Annual β_τ (Technology) and γ_τ (Know-How) coefficients from Equation 1 for plant *TFP* (logged TFPQ), under alternative fixed effects and the Sun and Abraham (2021) estimator. Baseline (plant and year FE) shown for reference. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications.

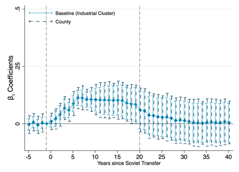
Back

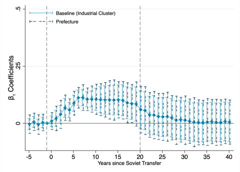
Alternative Clustering: Output

Technology

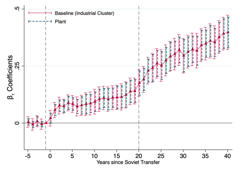
Plant	County	Prefecture

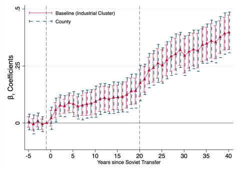


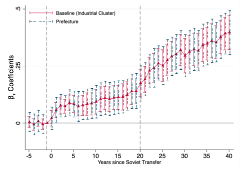




Know-How







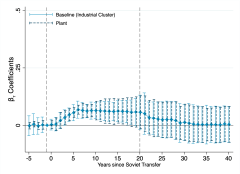
Notes. Annual β_τ (Technology) and γ_τ (Know-How) coefficients from Equation 1 for plant *output*, with standard errors clustered at the plant, county, and prefecture level, respectively. Baseline (plant and year FE) shown for reference.

◀ Back

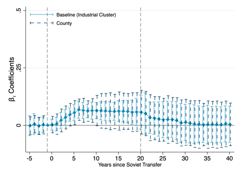
Alternative Clustering: TFP

Technology

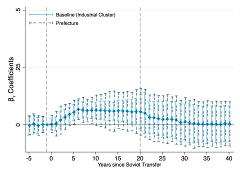
Plant



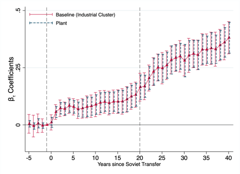
County

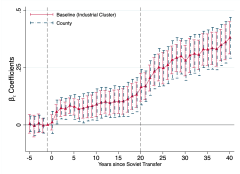


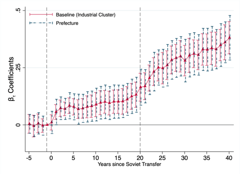
Prefecture



Know-How







Notes. Annual β_τ (Technology) and γ_τ (Know-How) coefficients from Equation 1 for plant *TFP* (logged TFPQ), with standard errors clustered at the plant, county, and prefecture level, respectively. Baseline (plant and year FE) shown for reference. Back

TFP, Technology Plants: Using US Prices

	Year 1	Year 5	Year 10	Year 20	Year 30	Year 40
Baseline (TFPQ, OLS)	0.005	0.055***	0.064***	0.057	0.013	0.004
	(0.015)	(0.018)	(0.018)	(0.038)	(0.041)	(0.040)
Using US Prices	0.002	0.067***	0.078***	0.065	0.019	0.005
	(0.020)	(0.021)	(0.025)	(0.056)	(0.041)	(0.039)

Notes. Annual β_τ coefficients from Equation 1 for plant *TFP* (logged TFPQ); *Using US Prices* recomputes TFPQ valuing output at US steel prices (Table C.2). SEs block-bootstrapped at the industrial-cluster level. Back

TFP, Know-How Plants: Using US Prices

	Year 1	Year 5	Year 10	Year 20	Year 30	Year 40
Baseline (TFPQ, OLS)	0.056***	0.078***	0.089***	0.165***	0.281***	0.381***
	(0.016)	(0.018)	(0.027)	(0.029)	(0.037)	(0.037)
Using US Prices	0.064***	0.095***	0.108***	0.201***	0.312***	0.420***
	(0.019)	(0.021)	(0.030)	(0.032)	(0.045)	(0.046)

Notes. Annual γ_τ coefficients from Equation 1 for plant *TFP* (logged TFPQ); *Using US Prices* recomputes TFPQ valuing output at US steel prices (Table C.2). SEs block-bootstrapped at the industrial-cluster level. Back

Alternative TFP Estimations: Physical Capital

	Year 1	Year 5	Year 10	Year 20	Year 30	Year 40
TFPQ, OLS (baseline)	0.005 (0.015)	0.055*** (0.018)	0.064*** (0.018)	0.057 (0.038)	0.013 (0.041)	0.004 (0.040)
TFPR, OLS	0.004 (0.020)	0.062*** (0.016)	0.070*** (0.025)	0.063 (0.050)	0.016 (0.040)	0.006 (0.039)
FS: LS=0.60, CS=0.40	0.003 (0.021)	0.065*** (0.018)	0.071*** (0.026)	0.065 (0.055)	0.018 (0.039)	0.005 (0.041)
FS: LS=0.66, CS=0.33	0.003 (0.020)	0.069*** (0.020)	0.072*** (0.025)	0.066 (0.052)	0.017 (0.042)	0.005 (0.039)
FS: LS=0.50, CS=0.50	0.003 (0.019)	0.068*** (0.019)	0.075*** (0.026)	0.068 (0.055)	0.019 (0.040)	0.004 (0.041)
Using US Prices	0.002 (0.020)	0.067*** (0.021)	0.078*** (0.025)	0.065 (0.056)	0.019 (0.041)	0.005 (0.039)
OP	0.004 (0.018)	0.054*** (0.020)	0.064*** (0.024)	0.056 (0.051)	0.015 (0.038)	0.005 (0.040)
LP	0.004 (0.019)	0.055*** (0.021)	0.063*** (0.025)	0.058 (0.052)	0.017 (0.040)	0.006 (0.041)
GNR	0.004 (0.019)	0.054*** (0.020)	0.064*** (0.025)	0.057 (0.051)	0.015 (0.049)	0.005 (0.040)
Excl. Scrapped Output	0.005 (0.015)	0.055*** (0.018)	0.064*** (0.018)	0.057 (0.038)	0.013 (0.041)	0.004 (0.040)
Excl. Non-usable Output	0.005 (0.015)	0.055*** (0.018)	0.064*** (0.018)	0.057 (0.038)	0.013 (0.041)	0.004 (0.040)

Notes. Selected annual β_τ coefficients from Equation 1 for plant TFP under alternative TFP-estimation methods (OLS TFPQ/TFPR; factor shares FS; US prices; Olley–Pakes; Levinsohn–Petrin; Gandhi et al.; and alternative output measures). $N = 13{,}984$. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications.

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Alternative TFP Estimations: Know-How

	Year 1	Year 5	Year 10	Year 20	Year 30	Year 40
TFPQ, OLS (baseline)	0.056*** (0.016)	0.078*** (0.018)	0.089*** (0.027)	0.165*** (0.029)	0.281*** (0.037)	0.381*** (0.037)
TFPR, OLS	0.060*** (0.018)	0.088*** (0.022)	0.096*** (0.028)	0.169*** (0.034)	0.301*** (0.040)	0.407*** (0.045)
FS: LS=0.60, CS=0.40	0.061*** (0.020)	0.087*** (0.021)	0.098*** (0.030)	0.170*** (0.032)	0.298*** (0.041)	0.405*** (0.047)
FS: LS=0.66, CS=0.33	0.059*** (0.019)	0.087*** (0.025)	0.097*** (0.031)	0.178*** (0.031)	0.299*** (0.039)	0.406*** (0.046)
FS: LS=0.50, CS=0.50	0.058*** (0.020)	0.090*** (0.022)	0.095*** (0.029)	0.177*** (0.035)	0.300*** (0.042)	0.404*** (0.048)
Using US Prices	0.064*** (0.019)	0.095*** (0.021)	0.108*** (0.030)	0.201*** (0.032)	0.312*** (0.045)	0.420*** (0.046)
OP	0.061*** (0.019)	0.090*** (0.022)	0.096*** (0.029)	0.165*** (0.033)	0.282*** (0.041)	0.380*** (0.044)
LP	0.062*** (0.019)	0.086*** (0.021)	0.095*** (0.028)	0.166*** (0.034)	0.281*** (0.040)	0.381*** (0.044)
GNR	0.061*** (0.018)	0.087*** (0.023)	0.096*** (0.027)	0.164*** (0.035)	0.381*** (0.041)	0.379*** (0.046)
Excl. Scrapped Output	0.062*** (0.016)	0.088*** (0.020)	0.097*** (0.025)	0.179*** (0.026)	0.299*** (0.041)	0.401*** (0.047)
Excl. Non-usable Output	0.065*** (0.014)	0.087*** (0.019)	0.098*** (0.024)	0.175*** (0.028)	0.295*** (0.044)	0.403*** (0.049)

Notes. Selected annual γ_τ coefficients from Equation 1 for plant TFP under alternative TFP-estimation methods (OLS TFPQ/TFPR; factor shares FS; US prices; Olley–Pakes; Levinsohn–Petrin; Gandhi et al.; and alternative output measures). $N = 13{,}984$. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications.

◂ Back

Higher Scientific Education and Human Capital

	STEM Universities (1)	Technical Schools (2)	College Graduates (3)	High-Skilled Workers (4)
Technology	0.009	-0.010	0.015	0.007
	(0.013)	(0.012)	(0.021)	(0.011)
Know-How	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. *Technology/Know-How* is 1 for counties where technology/know-how plants are located. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications. ***p<0.01, **p<0.05, *p<0.1.

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More Productive *Private* Firms in Counties with Know-How Plants

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

Notes. *Technology/Know-How* is 1 for plants in the same county and related to technology/know-how plants. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications. ***p<0.01, **p<0.05, *p<0.1.

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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)
Technology	0.015	0.012	0.018	0.016	0.012	0.004
	(0.021)	(0.027)	(0.009)	(0.014)	(0.018)	(0.006)
Know-How	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. *Technology/Know-How* is 1 for counties where technology/know-how plants are located. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications. ***p<0.01, **p<0.05, *p<0.1. Back