Technology Adoption and Late Industrialization

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USC/Unil/Bank-Al-Maghrib Workshop on “Small Business, Development and Growth”

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Late Industrialization and Technology Adoption

Late industrialization

- Divergent patterns of industrialization across developing countries in the postwar period
- Late industrialization: Driven by the adoption of foreign technology
  - South Korea, Taiwan, Turkey, Brazil

Technology adoption

- Direct productivity gains to adopting firms
- Local productivity (knowledge) spillover
- Challenge: Quantitatively/empirically not well-known due to the lack of data availability

Question

How do technology adoption and its local spillover contribute to late industrialization?

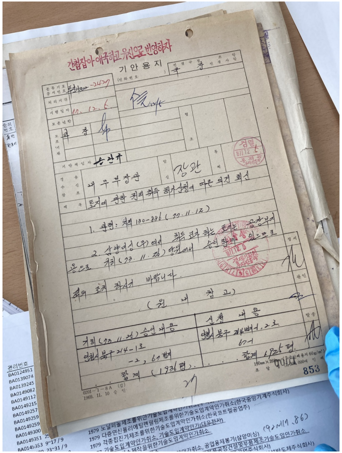
- South Korea in the 1970s
- Policy: Temporary adoption subsidy for heavy manufacturing sectors

What we do?

1. Construct a novel historical data set

- Universe of firm-level technology adoption contracts between South Korean and foreign firms
- Balance sheet
- Geographic information

$\rightarrow$ Can measure firm-level technology adoption directly



What we do?

1. Construct a novel historical data set

- Know-how on operation/engineering of plants/capital equipment
  - Blueprints/Training service
- Example:
  - Kolon (Korea) & Mitsui (Japan)
  - Production of Nonylphenol

ARTICLE III. SUPPLY OF TECHNICAL ASSISTANCE

1. MITSUI TOATSU shall transmit in documentary form to KOLON, TECHNICAL INFORMATION.

2. MITSUI TOATSU shall provide, upon the request of KOLON, the services of its technical personnel to assist KOLON in the engineering, construction and operation of the PLANT and in the quality and production control of LICENSED PRODUCT.
KOLON shall, for such services of technical personnel, pay the reasonable salaries, travelling and living expenses of such technical personnel while away from their own factories and offices.
The number of such technical personnel, the period of the services and the payment shall be discussed and decided separately between the parties.

3. MITSUI TOATSU shall receive KOLON's technical trainees at a plant designated by MITSUI TOATSU in order to train them

What we do?

1. Construct a novel historical data set

2. Empirical evidence
    - Direct productivity gains to adopters
    - Local productivity spillovers
    - Complementarity in Firms' Adoption Decisions

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3. Dynamic spatial model
    - Firms' technology adoption decisions & Local productivity spillover
    - Spillover operating with a time lag
        - $\rightarrow$ Dynamic complementarity in firms' adoption decisions
        - $\rightarrow$ Multiple steady states can arise
    - Permanent effect of one-time temporary adoption subsidy
        - $\rightarrow$ Move an economy to a new transition path to an alternative more-industrialized steady-state

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4. Counterfactual: What if the South Korean government had not provided temporary adoption subsidies?
    - Calibrated to the micro data and econometric estimates
    - Converge to a less-industrialized steady state
    - Heavy mfg. GDP share $\downarrow$ 15pp (2010 Korea $\rightarrow$ 2010 Mexico)

Data

Data (in brief)

Final data set Firm-level unbalanced panel data

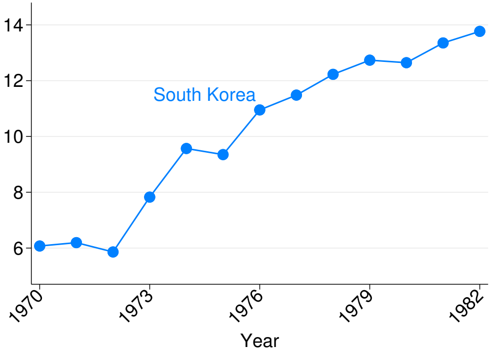
- *Adoption* : Dummy variable of South Korean firms' adoption status
  - Know-how (95%), 1,698 contracts, 690 unique firms, Heavy mfg 80%
- *Balance sheet* : Sales, employment, assets, fixed assets
- *Geographic information* : Location of production
- *Sample period* : 1970-1982
- *Sectors* : 10 mfg. sectors 4 heavy mfg. sectors
- *Coverage*
  - Adoption : Universe
  - Balance sheet : Emp. ≥ 50, 7,323 unique firms, covers 70% of mfg. gross output

Descriptive Statistics by Sector | Descriptive Statistics by Adoption Status | Classification of Sectors | Coverage | Figure: Balance Sheet Data

Historical Background on Late Industrialization in South Korea

Late Industrialization in South Korea and Technology Adoption

- Heavy mfg. GDP share (%)



Other Aggregate Statistics | Shares of Adopters | Patents | Longer Period

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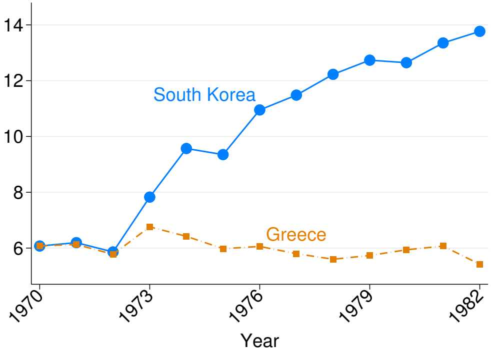

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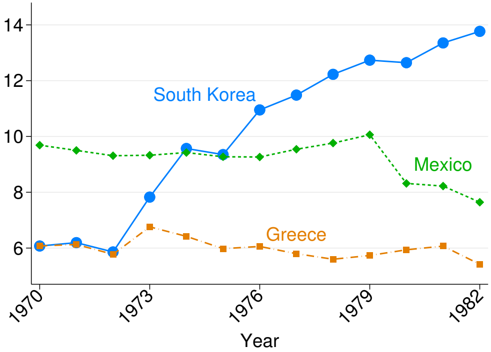

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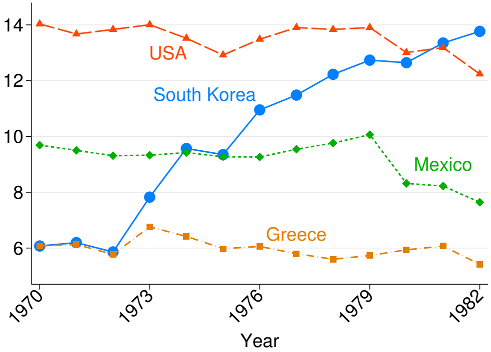

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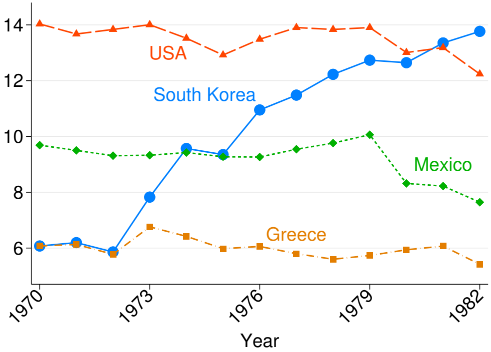
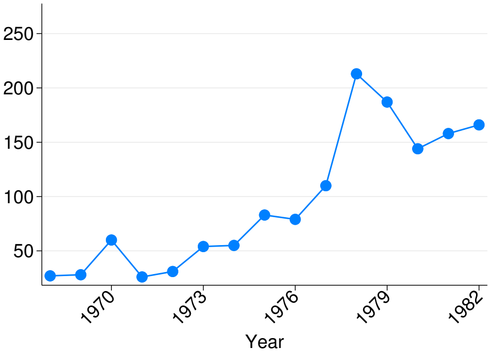


- # of new foreign technology adoption contracts made by the South Korean heavy mfg. firms



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Temporary Adoption Subsidy between 1973 and 1979

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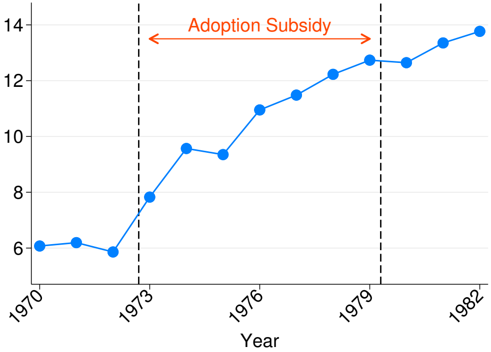

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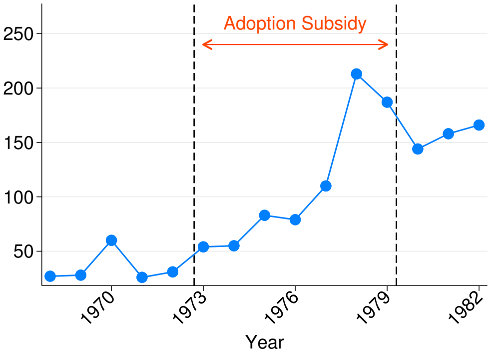

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Historical Background on Adoption Subsidy between 1973 and 1979

- HCI Drive: Targeted heavy mfg. sectors
  - chemicals, electronics, machinery, non-ferrous metal, shipbuilding, steel
- One of the main policy instruments: Subsidies for technology adoption
  - *"Without improving our underdeveloped technology, our nation will be unable to secure an independent national defense system ... which bodes ill for our chance of a peaceful reunification with North Korea."*
  - *"Considering our nation's current technological state, adopting foreign advanced technologies ... seem to be the most effective catching-up strategy."* (Science and Technology Annual, 1972)
- Temporary policy
  - Ended after President Park was assassinated in 1979

Back to Introduction Graph | HCI Drive Event Study | Institutional Background on Temporary Subsidies | Why Foreign Firms Made Contracts?

Empirical Evidence on the Firm-Level Effects of Technology Adoption

1. Direct Productivity Gains to Adopters
2. Local Productivity Spillovers
3. Complementarity in Firms' Adoption Decisions

Empirical Evidence: Direct Productivity Gains to Adopters

Direct Productivity Gains to Adopters: “Winners vs. Losers” Research Design

Econometric challenge: Endogenous adoption decisions $\rightarrow$ Selection bias

- Ideal empirical scenario: Random assignment of adoption status

Example | Descrpitive Stat | Descrpitive Stat: Foreign | Balance Test | Trade Pattern | Shares by Industry

Direct Productivity Gains to Adopters: “Winners vs. Losers” Research Design

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Winners vs. losers research design (Greenstone et al., 2010; Malmendier et al., 2018)

- Winner (the treated) : An adopter
- Loser (the control) : A non-adopter that tried but failed in the end
  1. Made a contract & approved by the government
  2. Foreign firms’ exogenous cancellations unrelated to South Korean firms

     E.g. (1) Changes of foreign firms’ management team, (2) Foreign firm’s bankruptcy

Example Descrpitive Stat Descrpitive Stat: Foreign Balance Test Trade Pattern Shares by Industry

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Matching procedure For each loser, we match a winner (34 pairs)

Step 1. Exactly match on sector and region

Step 2. Distance match on observable: log assets

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Identifying assumption A loser forms a valid counterfactual for a matched winner

1. The cancellations were exogenous to losers conditional on matched observables (sector, region, size)
2. Winners and losers are ex-ante similar in terms of both observables and unobservables.

Example | Descrpitive Stat | Descrpitive Stat: Foreign | Balance Test | Trade Pattern | Shares by Industry

Direct Productivity Gains to Adopters: Regression

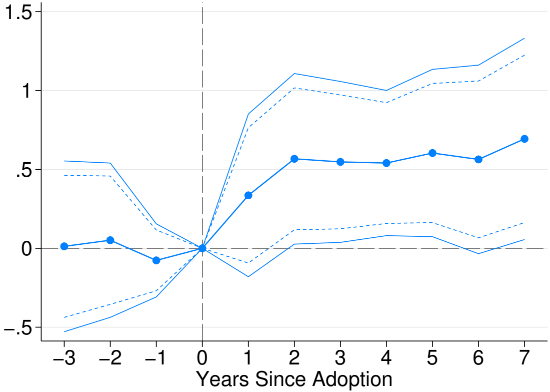
Event study

$$\log y_{ipt} = \sum_{\tau=-3}^{7} \beta_\tau D_{pt}^{\tau} + \sum_{\tau=-3}^{7} \beta_\tau^{diff} (D_{pt}^{\tau} \times \mathbb{1}[Adopt_{it}]) + \delta_i + \delta_p + \delta_t + \epsilon_{ipt}$$

- $D_{pt}^{\tau} := \mathbb{1}[t - \tau = t(p)]$: Event dummies
- $\mathbb{1}[Adopt_{it}]$: Adoption status
- δ_i, δ_p, δ_t : Firm, pair, year FEs

- *Dependent variables* : Log sales, revenue TFP
- *Sample* : Matched 34 pairs of winners and losers
- *Identifying variation* : Differences within pairs at event time τ
- *Cluster* : Two-way clustered at pair & firm

Technology adoption increased sales (50%) and revenue TFP (45%) of winners relative to losers.



Sales ↑ 50%

Matching: Asset Growth | Table | Labor Productivity | Input | Export | TWFE | Raw Data Plot | Pair-Time FEs | Placebo: Non-adopters

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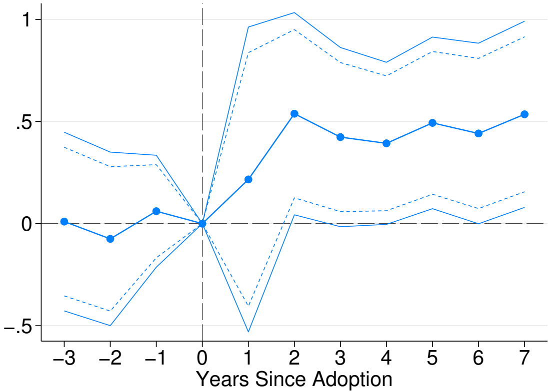

Revenue TFP ↑ 45%

Matching: Asset Growth | Table | Labor Productivity | Input | Export | TWFE | Raw Data Plot | Pair-Time FEs | Placebo: Non-adopters

Empirical Evidence: Local Productivity Spillover

Local Productivity Spillover

Spillover measure for firm *i*

Local Spillover: Examples

$$\text{Spill}_{inj(t-h)} = \sum_{k \in nj/\{i\}} \left\{ \frac{(1/dist_{ik})\mathbb{1}[\text{Adopt}_{k(t-h)}]}{\sum_{k' \in nj/\{i\}} (1/dist_{ik'})} \right\}$$

- $dist_{ik}$: distance between firm i and k
- $\mathbb{1}[\text{Adopt}_{k(t-h)}]$: lagged adoption status
- firm: i, k
- region: n
- sector: j
- time: t

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Regression model

Overlapping long-difference 1971-1979, 1972-1980

$$\triangle \log(\text{Sale}_{injt}) = \beta^S \triangle \text{Spill}_{inj(t-h)} + \triangle \delta_{njt} + \mathbf{X}'_{injt_0} \boldsymbol{\beta} + \triangle \epsilon_{injt}$$

- *Sample* : Never-adopters
- *Cluster* : Region & Conglomerate levels

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Econometric challenges

Spatially correlated shocks $\rightarrow$ Spurious correlation

- δ_{njt}: $34 mi^2$ ($90 km^2$) (Manhattan-sized)

  $\rightarrow$ Variation in distances to adopters of the same sector within narrowly defined regions

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Identifying assumption Distances to adopters are uncorrelated with non-adopters' unobservables conditional on δ_{njt}, δ_i, and controls.

Firms located closer to local adopters had higher sales growth.

Dep. Var.	log sales
	(1)
Spill	4.39***
	(1.54)
N	1079

- Interpretation: One std. spillover (0.33) $\uparrow$ $\rightarrow$ sales $\uparrow$ 14.5%
- Robustness: Local input sourcing market access, conglomerate FE, revenue TFP

Controls, Revenue TFP, Full Sample, Cross-Sector Spillover, Broader Level, Alternative Measure: Weighted Sum

Empirical Evidence: Complementarity in Firms' Adoption Decisions

Complementarity in Firms' Adoption Decisions

Regression model   Overlapping long-difference   1971-1979, 1972-1980

$$\triangle \mathbb{1}[\text{New Contract}_{injt}] = \beta^S \triangle \text{Spill}_{inj(t-h)} + \triangle \delta_{njt} + \mathbf{X}'_{injt_0} \boldsymbol{\beta} + \triangle \epsilon_{injt}$$

- *Sample* : Full-sample
- *Cluster* : Region & Conglomerate levels

Firms located closer to local adopters were more likely to adopt a new technology.

Dep. Var.	$\mathbb{1}$[New Contract]
	(1)
Spill	0.49***
	(0.18)
N	2689

- Interpretation: One std. spillover (0.33) $\uparrow$ $\rightarrow$ probability of making a new contract $\uparrow$ 1.5 pp
  - Annual average shares of firms making a new technology contract: 3%
- Robustness: Local input sourcing market access, conglomerate FE, revenue TFP

Controls

Theory (in brief)

Environment

Set-up

- Closed economy
- Discrete time: $t \in \{1, 2, 3, \ldots, \infty\}$
- One region, one sector
- Firms i
    - Monopolistically competitive
    - Fixed mass, $M = 1$
    - Heterogeneous productivity z_{it}
- Households
    - Inelastic labor supply
    - Income: wage & profits

Environment: Dynamics

Static decisions by agents

- Static technology adoption decisions by firms
  - (Trade-off) Direct productivity gains vs. Fixed adoption cost (units of final goods)
- Static consumption decisions by households

Source of dynamics

- Local spillover of adoption operating with one-period lag (Allen and Donaldson, 2021)
  - Externality: Amounts of adoption in $t-1$ affect local productivity in t

Technology Adoption

Firm productivity

$$z_{it} = \underbrace{\eta^{T_{it}}}_{\substack{\text{Direct} \\ \text{productivity gains}}} \times \underbrace{f(\lambda_{t-1})}_{\substack{\text{Local} \\ \text{spillover}}} \times \underbrace{\phi_{it}}_{\substack{\text{Exogenous} \\ \text{productivity}}}$$

Microfoundation-Nonrivalry Microfoundation-Learning Externality

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- $\eta > 1$: Direct productivity gains
- $T_{it} \in \{0, 1\}$: a binary adoption status
- $f(\lambda_{t-1})$: Local spillover
- λ_{t-1} : Share of adopters in the previous period
- ϕ_{it} : Exogenous productivity $\sim$ Pareto

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Spillover

$$f(\lambda_{t-1}) = exp(\delta\lambda_{t-1}), \qquad \delta\text{: Semi-elasticity}$$

Mapping to reduced-form estimates

- $\eta:$ $$\ln Sale_{it} = \underbrace{(\sigma-1)\ln(\eta)\mathbb{1}[Adopt_{it}]}_{\text{"Winners vs. losers"}} + \underbrace{(\sigma-1)\delta\lambda_{t-1} + (\sigma-1)\ln(w_t) + \ln(P_t^{\sigma-1}E_t)}_{\text{Absorbed out by exactly matching on region-sector}} + (\sigma-1)\ln\phi_{it}$$
- $\delta:$ $$\ln Sale_{it} = \underbrace{(\sigma-1)\delta\lambda_{t-1}}_{\text{Variation in distance}} + \underbrace{(\sigma-1)\ln(w_t) + \ln(P_t^{\sigma-1}E_t)}_{\text{Region-sector-time FE}} + (\sigma-1)\ln\phi_{it}$$

Microfoundation-Nonrivalry Microfoundation-Learning Externality

Analytical Results: Multiple Steady States

Net gains from adoption

$$\underbrace{\pi_{it}(T_{it}=1)-\pi_{it}(T_{it}=0)}_{\text{Gains from adoption}}-\underbrace{P_tF^T}_{\text{Fixed adoption cost}}=\underbrace{(\eta^{\sigma-1}-1)\frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\frac{w_t}{f(\lambda_{t-1})\phi_{it}}\right)^{1-\sigma}P_t^{\sigma-1}E_t}_{\text{Gains from adoption}}-\underbrace{P_tF^T}_{\text{Fixed adoption costs}}$$

Adoption productivity cutoff and adoption probability

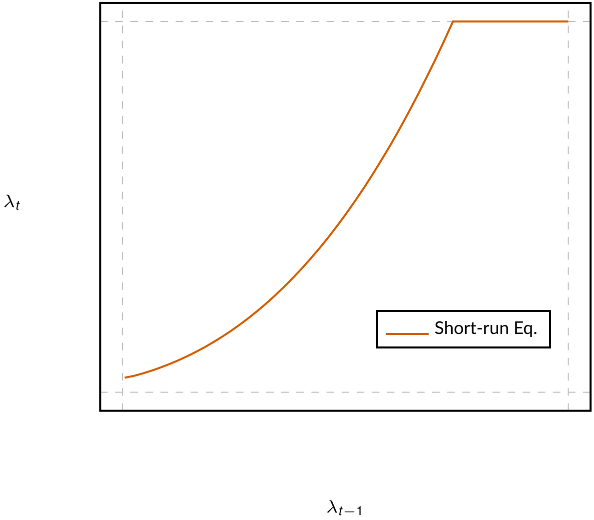
$$\bar{\phi}_t^T=\left[\frac{\sigma F^T(\frac{\sigma}{\sigma-1}w_t)^{\sigma-1}}{(\eta^{\sigma-1}-1)f(\lambda_{t-1})P_t^{\sigma-2}E_t}\right]^{\frac{1}{\sigma-1}},\qquad \lambda_t=\min\{(\bar{\phi}_t^T)^{-\theta},1\}$$

(Period-by-period) Short-run equilibrium λ_t^*

1. λ_t^* increases in λ_{t-1} $\rightarrow$ Dynamic complementarity
2. Unique short-run equilibrium for each t (no contemporaneous spillover)
   - Given initial λ_0, $\exists$ a unique equilibrium path

Closed-Form Expressions | Technical Assumptions | Firms' Maximization Problem & Sources of Dynamic Complementarity | Empirical Evidence on Dynamic Complementarity

Multiple Steady States



- Short-run Eq. (Red locus): $(\lambda^*_{t-1}, \lambda^*_t)$
  - Dynamic complementarity
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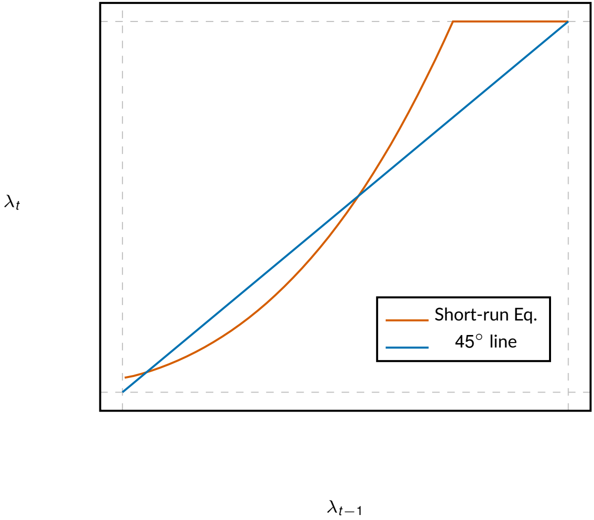
Multiple Steady States



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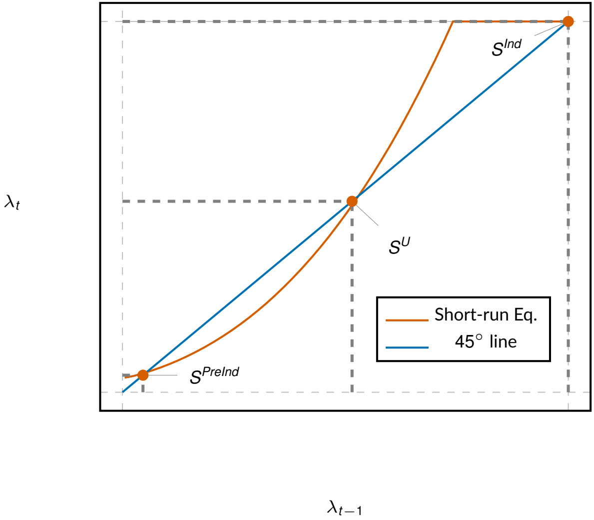

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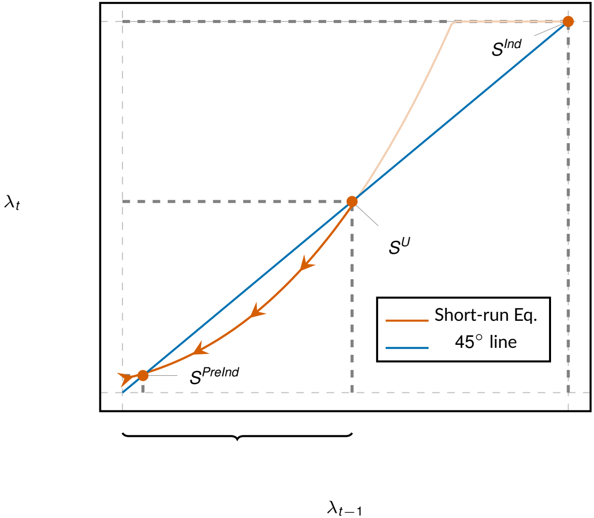

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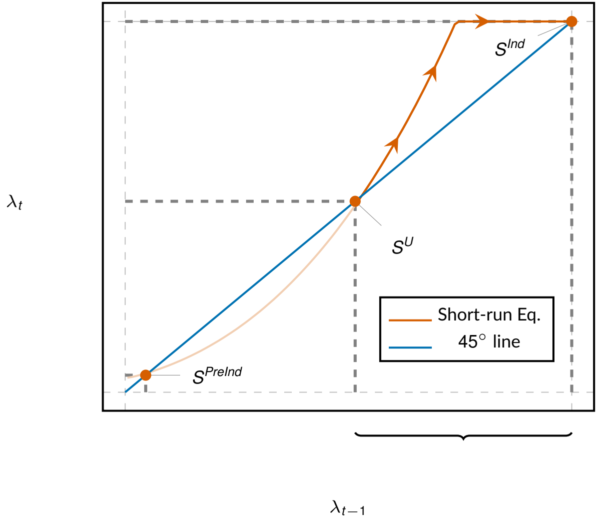

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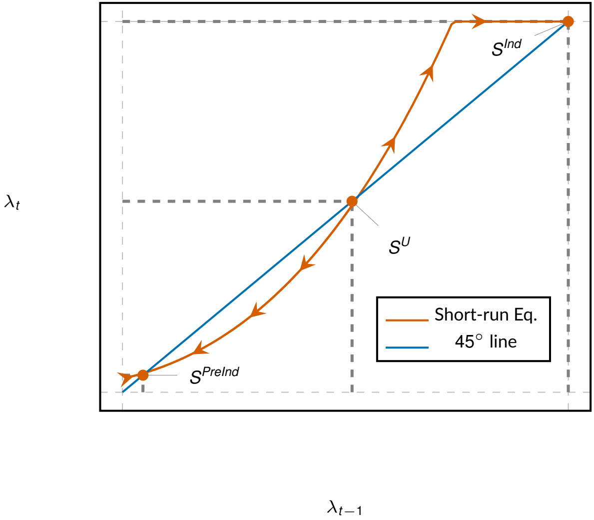

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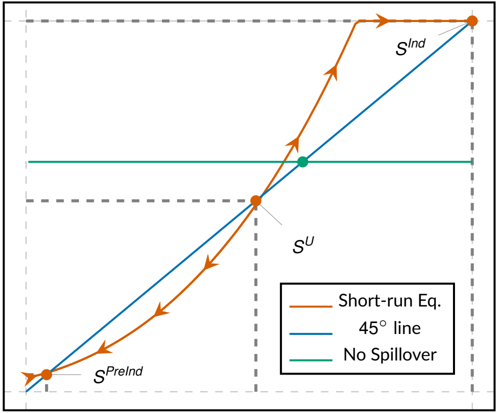
  - Dynamic complementarity $\rightarrow \lambda^*_t$ increases in λ^*_{t-1}
- Steady state condition (45° blue line)
  - $\lambda_t = \lambda_{t-1}$
- Pareto-ranked by λ^*
- Initial condition (history) matters

Multiple Steady States

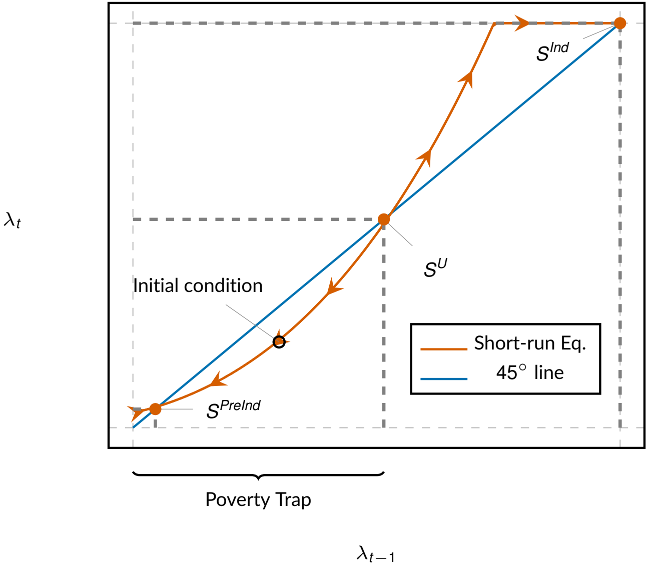
λ_t



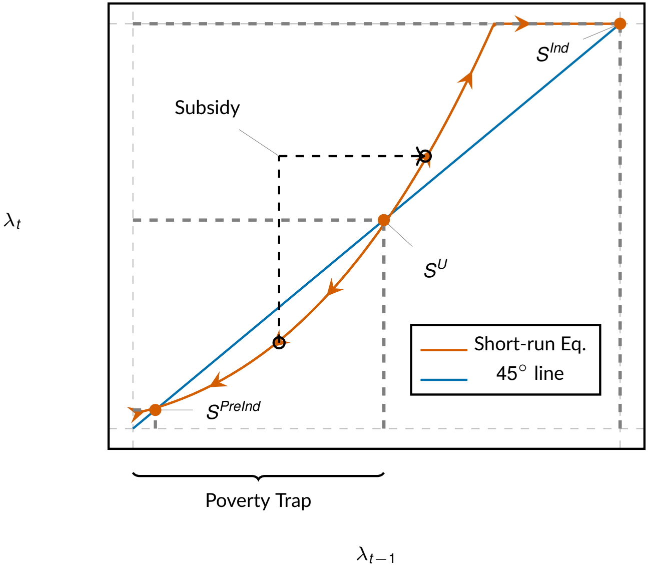
λ_{t-1}

- Short-run Eq. (Red locus): $(\lambda^*_{t-1}, \lambda^*_t)$
  - Dynamic complementarity
    $\rightarrow \lambda^*_t$ increases in λ^*_{t-1}
- Steady state condition (45° blue line)
  - $\lambda_t = \lambda_{t-1}$
- Pareto-ranked by λ^*
- Initial condition (history) matters
- Nonlinearity and spillover
  - No spillover ($\delta = 0$)
    $\rightarrow$ Unique steady state

Multiple Steady States: Role of Temporary Subsidy for the Adoption



Multiple Steady States: Role of Temporary Subsidy for the Adoption



Full Quantitative Model

Set-up

- Small open economy: Home & Foreign (Rodrik, 1995; Irwin, 2021)
- N regions: n, m 42 regions
- J sectors: j, k (1) Commodity, (2) Light mfg., (3) Heavy mfg., (4) Service
  - Technology adoption only available in heavy mfg.
  - Service is non-tradable across regions and countries

Costly trade

Firms

Households

Subsidy

Equilibrium

Full Quantitative Model

Set-up

Costly trade

- Internal trade : Iceberg trade cost: τ_{nmj}
- International trade : Iceberg trade cost: τ^x_{nj} , Fixed export cost: F^x_j (Melitz, 2003)

Firms

Households

Subsidy

Equilibrium

Full Quantitative Model

Set-up

Costly trade

Firms

- Static adoption & export decisions Firms' Maximization Problem
- Roundabout production Production

Households

Subsidy

Equilibrium

Full Quantitative Model

Set-up

Costly trade

Firms

Households

- (1) Consumption: Cobb-Douglas preference
- (2) (Myopic) Costly migration decisions (Young, 1995; Lucas, 2004) Preference & Labor Mobility

Subsidy

Equilibrium

Full Quantitative Model

Set-up

Costly trade

Firms

Households

Subsidy

- Input subsidy for adopters financed by labor tax Adoption Subsidy Institutional Background on Labor Tax
- Balanced government budget each period

Equilibrium

Taking the Model to the Data

Calibration Procedure

Calibration strategy Match cross-sectional data in 1972, 1976, 1980

Subsidies Subsidy rate $\bar{s}$ in 1976, 1980

- Identifying moment: uniquely identify $\bar{s}$ (under simplifying assumptions) $\Rightarrow$ 11%
- Intuition
  1. η, δ: Measured benefits from adoption
  2. Conditional on measured benefits, increases in shares of adopters in 1976 and 1980 relative to 1972 are attributable to subsidies.

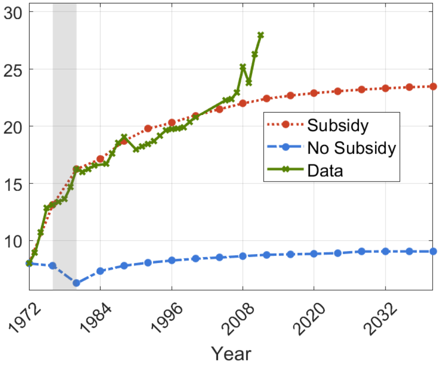
Structural parameters & Geographic fundamentals

- Method of moments

Identification of Subsidies | Externally Calibrated Parameters | Method of Moments | Model Fit | Non-Targeted Moments: Heavy Mfg. Regional Distribution

Quantitative Results: Evaluation of the Policy

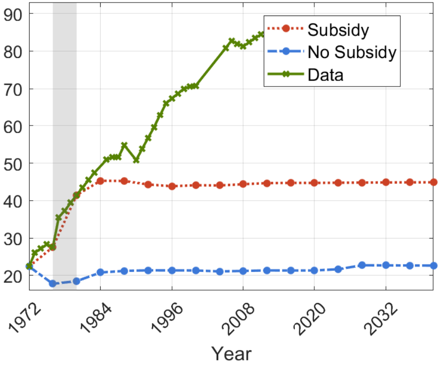
If subsidies had not been provided, heavy mfg. GDP and export shares would have been 15pp and 20pp permanently lower.



Heavy mfg. GDP share (%)

Amplifying Factors | Light Mfg. Export Share | Employment Share | Aggregate Welfare

If subsidies had not been provided, heavy mfg. GDP and export shares would have been 15pp and 20pp permanently lower.



Heavy mfg. export share (%)

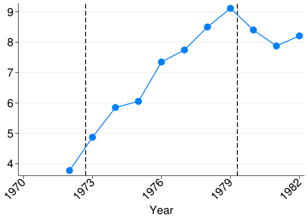
Amplifying Factors | Light Mfg. Export Share | Employment Share | Aggregate Welfare

Conclusion

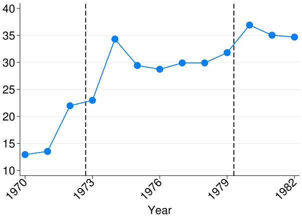
Conclusion

1. **New data**
   - Digitized archival data on firm-level technology adoption activities
2. **Empirics**
   - Technology adoption: (1) Direct gains, (2) Local spillover, (3) Complementarity
3. **Quantification**
   - Subsidized technology adoption can explain South Korea's industrialization patterns
   - Multiple steady states generated by spillover/complementarity

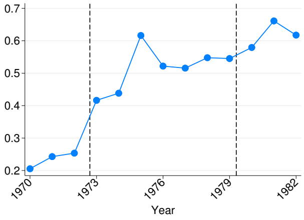
Other Measures



A. Heavy mfg. employment share



B. Heavy mfg. export share



C. Heavy mfg. Balassa index, RCA

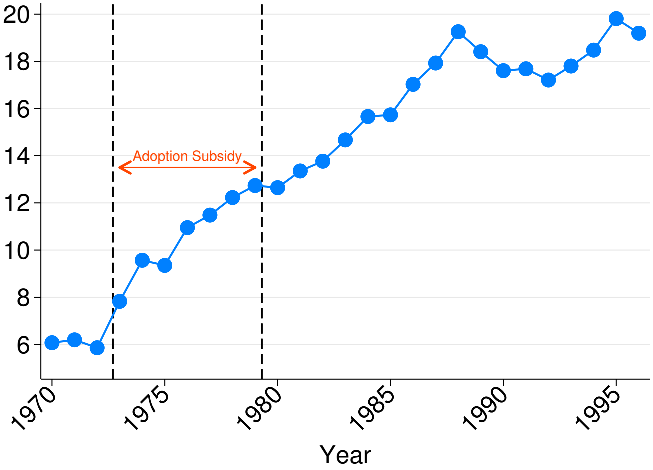
Back to Introduction Graph

Historical Background on Adoption Subsidy between 1973 and 1979

- HCI Drive: Targeted heavy mfg. sectors
  - chemicals, electronics, machinery, non-ferrous metal, shipbuilding, steel
- One of the main policy instruments: Subsidies for technology adoption
  - *"Without improving our underdeveloped technology, our nation will be unable to secure an independent national defense system ... which bodes ill for our chance of a peaceful reunification with North Korea."*
  - *"Considering our nation's current technological state, adopting foreign advanced technologies ... seem to be the most effective catching-up strategy."* (Science and Technology Annual, 1972)
- Temporary policy
  - Ended after President Park was assassinated in 1979

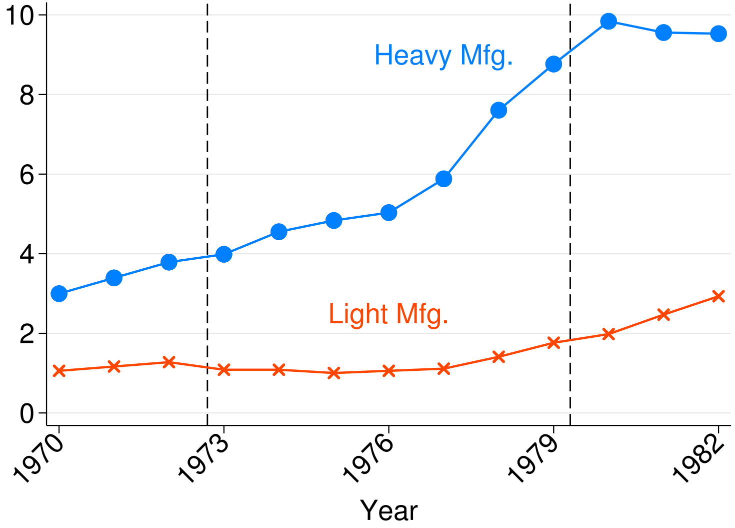
Back to Introduction Graph | HCI Drive Event Study | Institutional Background on Temporary Subsidies | Why Foreign Firms Made Contracts?

Heavy Mfg. GDP Shares



Back to Introduction Graph

Shares of Adopters (%)



Back to Introduction Graph

Descriptive Statistics by Sector

	All mfg. (1)	Heavy mfg. (2)	Light mfg. (3)
	Firm Balance Sheet		
ln(Sales)	15.65	15.54	15.75
	(1.93)	(1.94)	(1.91)
ln(Assets)	15.14	15.10	15.18
	(1.77)	(1.76)	(1.77)
ln(Fixed Assets)	13.96	13.94	13.98
	(1.97)	(1.93)	(1.99)
ln(Emp)	5.17	5.03	5.29
	(1.32)	(1.32)	(1.31)
	Technology Adoption		
$\mathbb{1}$[Ever Adopt]	0.15	0.23	0.08
	(0.36)	(0.42)	(0.07)
# (firms)	7,323	3,477	3,846
N	43,720	20,497	23,223

Back to Data

Descriptive Statistics by Ever-Adoption Status

	All firms (1)	Ever-Adopter (2)	Never-Adopter (3)
ln(Sales)	15.63	17.12	15.39
	(1.93)	(1.83)	(1.83)
ln(Assets)	15.14	16.81	14.93
	(1.76)	(1.77)	(1.65)
ln(Fixed Assets)	13.95	15.70	13.74
	(1.96)	(1.95)	(1.85)
ln(Emp)	5.17	6.09	5.03
	(1.32)	(1.45)	(1.25)
# (firms)	7,323	690	6,633
N	43,853	3,704	40,149

Back to Data

Classification of Sectors

	Aggregated Industry	Industry
Heavy Mfg.	(i) Chemicals, Petrochemicals, Rubber, & Plastic Products	Coke oven products (231) Refined petroleum products (232) Basic chemicals (241) Other chemical products (242) Man-made fibres (243) except for pharmaceuticals and medicine chemicals (2423) Rubber products (251) Plastic products (252)
	(ii) Electrical Equipment	Office, accounting, & computing machinery (30) Electrical machinery and apparatus n.e.c. (31) Ratio, television and communication equipment and apparatus (32) Medical, precision, and optical instruments, watches and clocks (33)
	(iii) Basic & Fabricated Metals	Basic metals (27) Fabricated metals (28)
	(iv) Machinery & Transport Equipment	Machinery and equipment n.e.c. (29) Motor vehicles, trailers and semi trailers (34) Building and repairing of ships and boats (351) Railway and tramway locomotives and rolling stock (352) Aircraft and spacecraft (353) Transport equipment n.e.c. (359)
Light Mfg.	(v) Food, Beverages, & Tobacco	Food products and beverages (15) Tobacco products (16)
	(vi) Textiles, Apparel, & Leather	Textiles (17) Apparel (18) Leather, luggage, handbags, saddlery, harness, and footwear (19)
	(vii) Manufacturing n.e.c.	Manufacturing n.e.c. (369)
	(viii) Wood, Paper, Printing, & Furniture	Wood and of products, cork (20) Paper and paper products (21) Publishing and printing (22) Furniture (361)
	(ix) Pharmaceuticals & Medicine Chemicals	pharmaceuticals and medicine chemicals (2423)
	(x) Other Nonmetallic Mineral Products	Glass and glass products (261) on-metallic mineral products n.e.c. (269)

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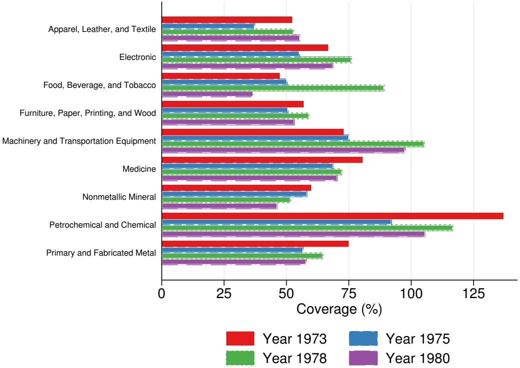
Coverage

$$\sum_i Sale_{ijt} / \text{Gross Ouput}_{jt}^{IO}$$



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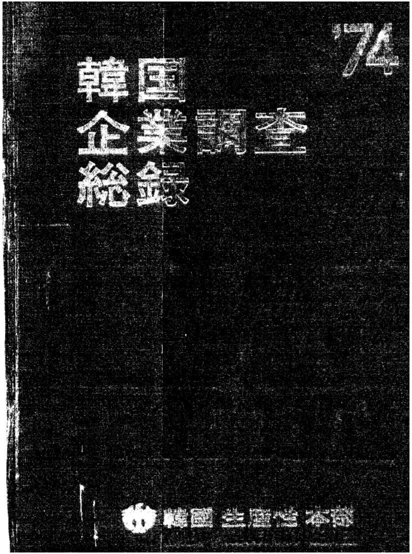
Source: Balance Sheet Data



Ⅲ. 製 造 業

流動資産(千원)	23,797	37,984	118,499
固定資産(〃)	41,846	46,063	52,418
繰延資産(〃)	—	—	716
流動負債(〃)	41,707	48,321	110,158
資 本 金(〃)	5,500	5,500	5,500
剰 餘 金(〃)	18,436	30,226	55,975
賣出實績			
賣 出 額(千원)	64,188	133,705	—
純 利 益(〃)	7,834	14,064	34,930

資産・資本	1971年	1972年	1973年
總 資 産(千원)	97,789	158,235	227,050
流動資産(〃)	73,033	134,932	201,765
固定資産(〃)	24,756	22,432	24,438
繰延資産(〃)	—	871	847
流動負債(〃)	60,896	111,813	163,489
資 本 金(〃)	8,500	8,500	8,500
剰 餘 金(〃)	28,393	37,922	55,051
賣出實績			
賣 出 額(千원)	139,547	311,475	536,975
輸出額(千弗)	424	828	1,420
純 利 益(千원)	862	10,846	22,013
配 當 率(%)	—	—	50

耕 熙 漁 網 (株)
(Kyung Hi Fishing Net Mfg. Co., Ltd.)

〔設立年月日〕 1968.3.12 〔營業種目〕 漁網, 로프製造業
〔本社・工場〕 釜山市影島區東三洞232-1 ⑬ 4111-7
〔營 業 鑑 札〕 603-61-0088 〔本社郵便番號〕 606
〔Cable〕 KYUNGHI BUSAN
〔서울事務所〕 中區明洞2街52-13(明洞빌딩) ㉘ 8693, 5297 ㉘ 4246
〔主要營業所〕 (耕熙商社) 釜山市中區南浦洞1街22 ㉓ 0273
(海外支社) 20, Efeson Nea Smyrni Athens, Greece
〔任 員〕 (代)安健一 (專)裵永學 (常)安秀正
〔從 業 員〕 380人
〔主製品의 年産能力〕 Nylon 漁網안승 Rope 540M/T PE, PP, 漁網, 로프, 안승 500M/T 기타 7,200kg
〔施 設 規 模〕 編網機 38台, 撚糸機 21台, Rope機 14台, 延出機 4台, 染色機 2台, 熱處理機 2台, 其他 施設 60餘台
〔經營實績 年間對比〕

資産・資本	1971年	1972年	1973年
總 資 産(千원)	310,911	419,887	506,924
流動資産(〃)	164,847	285,570	369,237
固定資産(〃)	141,967	129,429	132,757
繰延資産(〃)	4,097	4,888	4,930
流動負債(〃)	218,564	339,052	404,882
固定負債(〃)	62,729	55,544	56,366
資 本 金(〃)	20,000	20,000	20,000
剰 餘 金(〃)	9,118	5,291	52,676
賣出實績			
賣 出 額(千원)	409,251	468,838	745,084
輸出額(千弗)	814	807	1,521
純 利 益(千원)	3,990	2,673	22,385

啓 成 產 業 (株)
(Kesung San-up Co., Ltd.)

〔設立年月日〕 1958.11.8 〔營業種目〕 종이기製造 및 輸出業
〔本 社〕 서울特別市中區明洞1街5-1 ㉘ 5675, 8353 ㉘ 7575
〔營 業 鑑 札〕 201-63-4773 〔本社郵便番號〕 100
〔Cable〕 KUKJEPLATE SEOUL 〔私書函〕 C.P.O. Box 434
〔工 場〕 (종이기) 慶南馬山市石田洞160 ① 7702
〔任 員〕 (代)李秉炯 (專)李炳煥
〔經營實績 年間對比〕

鷄 龍 타 올 工 業 社

〔設立年月日〕 1964.7.20 〔營業種目〕 타올製造業
〔本 社〕 忠南大田市弘道洞92 ② 1532
〔營 業 鑑 札〕 306-31-0024 〔本社郵便番號〕 300
〔任 員〕 (代)姜紋淵
〔主製品의 年産能力〕 타올 400千打
〔施 設 規 模〕 타올織機 7台
〔購入原材料年間消費量〕 綿糸 25,000kg
〔經營實績 年間對比〕

資産・資本	1972年	1973年
總 資 産(千원)	25,000	25,000
流動資産(〃)	15,000	15,000
固定資産(〃)	5,000	5,000
繰延資産(〃)	5,000	5,000
流動負債(〃)	2,000	2,000
固定負債(〃)	1,000	1,000
資 本 金(〃)	20,000	20,000
剰 餘 金(〃)	2,000	2,000
賣出實績		
賣 出 額(千원)	15,000	20,000
純 利 益(〃)	700	1,000

高 麗 毛 織 (株)
(Korea Woolen Textile Co., Ltd.)

〔設立年月日〕 1951.4.17 〔營業種目〕 紡毛織物製造業
〔本社・工場〕 慶南馬山市午東洞17 ① 3121-2
〔營 業 鑑 札〕 608-61-0025 〔本社郵便番號〕 610
〔서울事務所〕 中區茶洞117(羅田빌딩700號) ㉘ 6832
〔任 員〕 (代)韓泰日 (專)韓正大 (常)韓正才, 金進哲, 黃騰桂
〔從 業 員〕 328人
〔主製品의 年産能力〕 紡毛織 600千yds
〔施 設 規 模〕 力織機 60台, 精紡機 1,810錘
〔經營實績 年間對比〕

資産・資本	1971年	1972年	1973年
總 資 産(千원)	538,768	544,055	623,688
流動資産(〃)	364,320	372,036	450,247
固定資産(〃)	174,448	172,019	173,441
流動負債(〃)	1,065,764	1,160,764	1,367,875
資 本 金(〃)	92,700	100,804	127,800

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Back to Data

Why foreign firms made adoption contracts?

Example: POSCO and Nippon Steel Company (NSC)

- Construction/Operation of integrated steel mills

Reasons

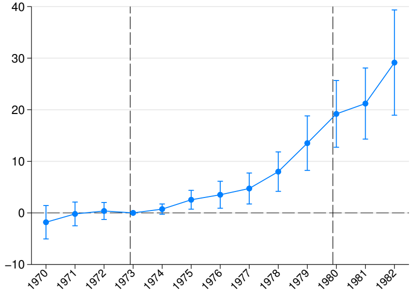
1. Profits: 20% of the total annual export of plant engineering of *NSC*
2. Transferred standardized (but still modern) technology but not the frontier technology
    - Refused to share technology related to computarization
3. Did not expect POSCO's success
    - *Saito, CEO of NSC* : "POSCO's rate of absorbing adopted technologies is very fast ... POSCO hit us like a boomerang."
    - In 1981, refused to make new contracts

Back to Historical Background

The Impact of the Policy on Firms' Adoption Decisions

$$100 \times \mathbb{1}[Adopt_{it}] = \sum_{\tau=-3}^{9} \beta^{\tau} D_t^{\tau} + \delta_i + \epsilon_{it},$$

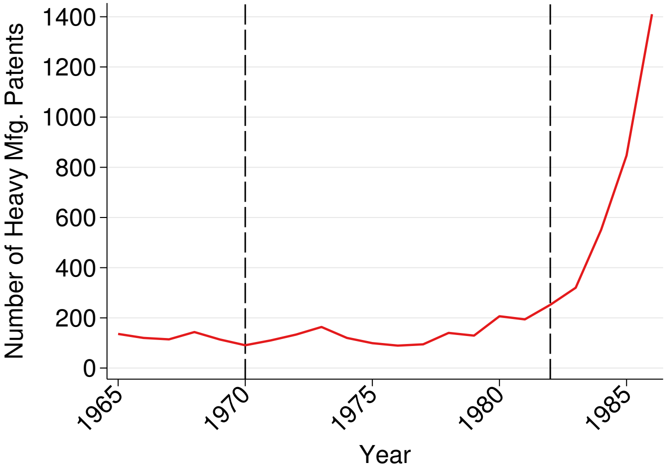
- *Sample*: Heavy mfg. firms



- Interpretation: In 1980, 20% increases in adoption relative to 1973

Back to Historical Background

The Number of Heavy Manufacturing Patents



Back to Historical Background

Institutional Background on Temporary Subsidies

Allocation of foreign credits (Choi and Levchenko, 2021)

- *Foreign Capital Inducement Act of Korea*
  - Strictly regulating financial contracts between domestic and foreign firms
  - Selectively allocated to the targeted firms or sectors
- Conditional on approvals, the government guaranteed to pay back

  $\Rightarrow$ Firms could borrow at a lower interest rate

Subsidized industrial technology adoption

- Direct costs of technology adoption
- Capital equipment related to adopted technologies

Back to Historical Background

Example: Kangwon and Brohel

Original

K27323
MAY 31 1977 HE770531-121

ATTN: MR. WERNER BOECKLER, PRESIDENT

RE: TECHNICAL COLLABORATION AGREEMENT FOR DECK MACHINERY.

SINCE ENTERING INTO THE ABOVE AGREEMENT,
WE, KANGWON, HAVE PERFORMED ALL OUR OBLIGATIONS IMPOSED UPON
US BY THE AGREEMENT.
HOWEVER, WE HAVE NOT RECEIVED SATISFACTORY RESPONSE IN CONNECTION
WITH PROMOTING OUR SALES ACTIVITY WITH OUR CUSTOMERS IN KOREA
ON ACCOUNT OF YOUR FAILURE TO SUPPLY US WITH ALL THE NECESSARY
DATA STIPULATED IN THE ARTICLE 1 AND 2 OF THE AGREEMENT.
THEREFORE WE REGRET TO NOTIFY YOU, ACCORDING TO THE ARTICLE
17 OF THE AGREEMENT, TO TERMINATE THIS AGREEMENT.
REGARDING THE INITIAL PAYMENT OF DM35,000 REMITTED TO YOU BY US
ON DEC. 13, 1976 IN CONNECTION WITH THIS AGREEMENT.
PLS BE REQUESTED BY US TO IMMEDIATELY REMIT US THE AMOUNT THRU
KOREA EXCHANGE BANK SEOUL.

I.W. CHUNG, PRESIDENT
KANGWON INDUSTRIAL CO., LTD. (5)

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Back to Research Design

“Winners vs. Losers” Research Design: Descriptive Statistics

	Winner				Loser				t-Statistics
	Mean	Med.	SD	Obs.	Mean	Med.	SD	Obs.	(Col. 1 - Col. 5)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
log sales	17.80	18.21	2.22	133	18.46	18.45	1.78	131	2.36 [0.13]
log employment	7.34	7.60	1.23	109	7.07	7.19	1.54	130	0.23 [0.64]
log fixed assets	17.15	17.10	2.26	162	17.19	17.64	2.26	158	0.01 [0.93]
log assets	18.00	17.99	2.10	162	18.12	18.40	2.08	158	0.07 [0.80]
log value-added/emp	9.57	9.70	1.26	102	9.95	9.62	1.35	122	1.55 [0.22]

Back to Research Design

"Winners vs. Losers" Research Design: Covariate Balance Test

Dep. Var. $\mathbb{1}[Adopt_{it}]$	Bivariate		Multivariate	
	(1)	(2)	(3)	(4)
log sales	-0.04 (0.03)	-0.1 (0.07)	-0.49 (0.14)***	0.14 (0.47)
N	264	262		
log employment	0.04 (0.03)	0.05 (0.07)	0.29 (0.15)*	-0.36 (0.5)
N	239	238		
log fixed assets	0.00 (0.02)	0.02 (0.07)	-0.02 (0.16)	0.16 (0.22)
N	319	319		
log assets	0.00 (0.02)	0.00 (0.08)	0.22 (0.21)	0.03 (0.33)
N	213	212		
log labor productivity	-0.06 (0.03)	-0.06 (0.06)	0.27 (0.14)*	-0.36 (0.49)
N	224	221	224	221
F-test [p-val]			4.55 [0.00]	0.72 [0.61]
Year FE	✓	✓	✓	✓
Pair FE		✓		✓

Back to Research Design

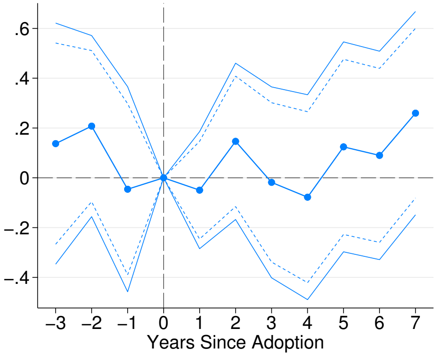
Descriptive Statistics of Patenting Activities by Foreign Contractors: Winners vs. Losers Design Samples

	Winner				Loser				t-Statistics (Col. 1 - Col. 5)	
	Mean	Med.	SD	Obs.	Mean	Med.	SD	Obs.		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	
Panel A. Yearly Measures										
$\ln(\text{Patent}+1)$	1.54	0.00	2.11	34	1.73	0.00	2.55	34	0.14	[0.71]
$\ln(\text{Citation}+1)$	1.71	0.00	2.36	34	2.06	0.00	2.88	34	0.34	[0.57]
$\mathbb{1}[\text{Patent}>0]$	0.44	0.00	0.50	34	0.39	0.00	0.49	34	0.24	[0.63]
$\mathbb{1}[\text{Citation}>0]$	0.42	0.00	0.50	34	0.42	0.00	0.50	34	0.00	[1.00]
Panel B. Cumulative Measures										
$\ln(\text{Cum. Patent}+1)$	2.20	0.00	2.72	34	2.57	1.15	3.13	34	0.35	[0.56]
$\ln(\text{Cum. Citation}+1)$	2.39	0.00	2.94	34	2.85	1.50	3.41	34	0.46	[0.50]
$\mathbb{1}[\text{Cum. Patent}>0]$	0.47	0.00	0.51	34	0.56	1.00	0.50	34	0.58	[0.45]
$\mathbb{1}[\text{Cum. Citation}>0]$	0.47	0.00	0.51	34	0.56	1.00	0.50	34	0.52	[0.48]

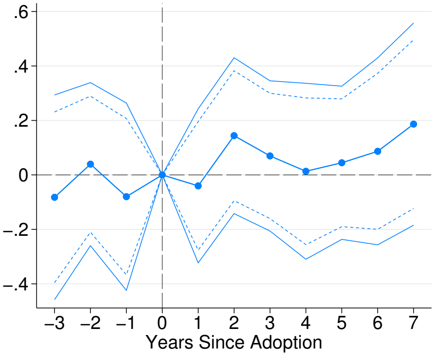
Back to Research Design

“Winners vs. Losers” Research Design: Placebo

Matching Non-adopters & losers



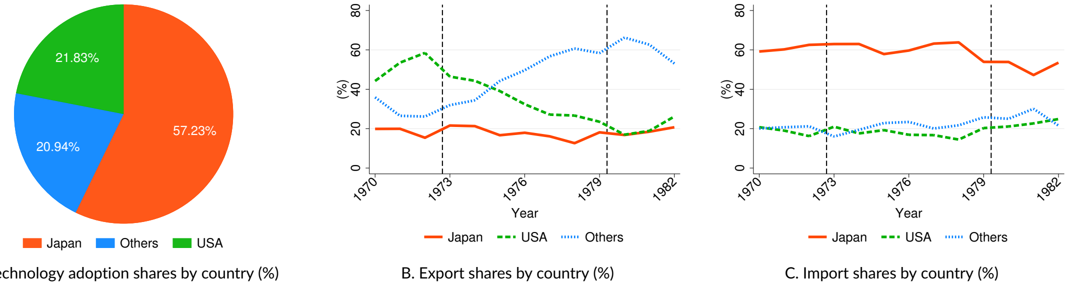
A. Log sales



B. Log revenue TFP

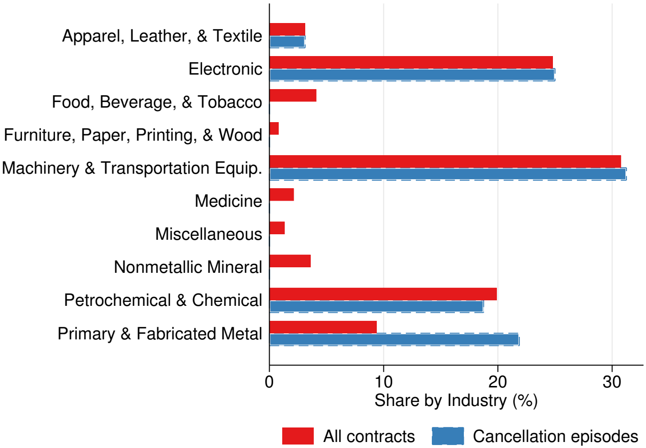
Back to Research Design

Sources of Technology Adoption and Trade Patterns



Back to Research Design

Shares of Contracts by Industry



Back to Research Design

Dep. Var.	log sales	log labor productivity	log revenue TFP			
			W. (2009)	ACF (2015)	LP (2003)	OLS
	(1)	(2)	(3)	(4)	(5)	(6)
3 years before event	0.00	−0.09	0.01	0.06	0.04	0.00
	(0.27)	(0.41)	(0.24)	(0.30)	(0.24)	(0.29)
2 years before event	0.07	−0.36	−0.11	−0.18	−0.08	−0.19
	(0.24)	(0.46)	(0.24)	(0.34)	(0.24)	(0.34)
1 year before event	−0.10	−0.02	0.04	0.10	0.06	0.08
	(0.12)	(0.23)	(0.15)	(0.19)	(0.15)	(0.19)
Year of event						
1 year after event	0.31	0.28	0.22	0.37	0.23	0.33
	(0.25)	(0.41)	(0.37)	(0.38)	(0.37)	(0.39)
2 years after event	0.53*	0.64**	0.56**	0.71**	0.56**	0.67**
	(0.27)	(0.30)	(0.26)	(0.30)	(0.26)	(0.29)
3 years after event	0.47*	0.62**	0.41*	0.66**	0.43*	0.63**
	(0.26)	(0.29)	(0.23)	(0.28)	(0.23)	(0.27)
4 years after event	0.48**	0.62**	0.42*	0.67**	0.45**	0.63**
	(0.23)	(0.27)	(0.21)	(0.25)	(0.21)	(0.24)
5 years after event	0.58**	0.43	0.52**	0.64**	0.52**	0.57*
	(0.26)	(0.36)	(0.21)	(0.29)	(0.23)	(0.29)
6 years after event	0.54*	0.55*	0.46**	0.59**	0.46*	0.56**
	(0.29)	(0.28)	(0.23)	(0.29)	(0.24)	(0.27)
7 years after event	0.66**	0.56*	0.57**	0.69**	0.58**	0.67**
	(0.31)	(0.32)	(0.23)	(0.29)	(0.23)	(0.28)
N	951	835	827	827	827	827

Back to Direct Productivity Gains Results

Direct Productivity Gains: Winners were 29% more likely to become an exporter

Data KIS-VALUE

- Exports after 1980
- Coverage is smaller than the main balance sheet data

Regression Model Pooled OLS 7,8 years after the event

$$\mathbb{1}[\text{Export}_{ip,t(p)+\tau}] = \beta^{export} \times \mathbb{1}[Adopt_{ip,t(p)}] + \delta_{p\tau} + \epsilon_{ip,t(p)+\tau}, \qquad \tau \in \{7,8\}$$

- $\mathbb{1}[\text{Export}_{ip,t(p)+\tau}]$: Export status τ years after the event

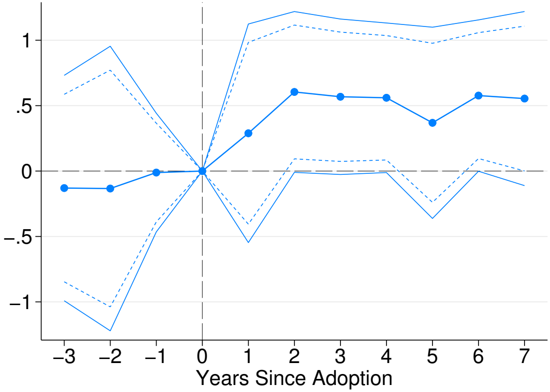
Back to Direct Productivity Gains Results

Direct Productivity Gains: Winners were 29% more likely to become an exporter

Dep. Var.	$\mathbb{1}$[Export]			*asinh*(Export)		
Years after the event (τ)	$\tau = 7, 8$	$\tau = 7$	$\tau = 8$	$\tau = 7, 8$	$\tau = 7$	$\tau = 8$
	(1)	(2)	(3)	(4)	(5)	(6)
Adopt	0.29^{**}	0.26^{*}	0.32^{**}	5.25^{**}	4.75^{*}	5.79^{**}
	(0.13)	(0.13)	(0.14)	(2.40)	(2.49)	(2.60)
p-val (CGM)	[0.06]	[0.04]	[0.01]	[0.04]	[0.08]	[0.04]
# cluster (pair)	23	23	22	23	23	22
N	90	46	44	90	46	44

Back to Direct Productivity Gains Results

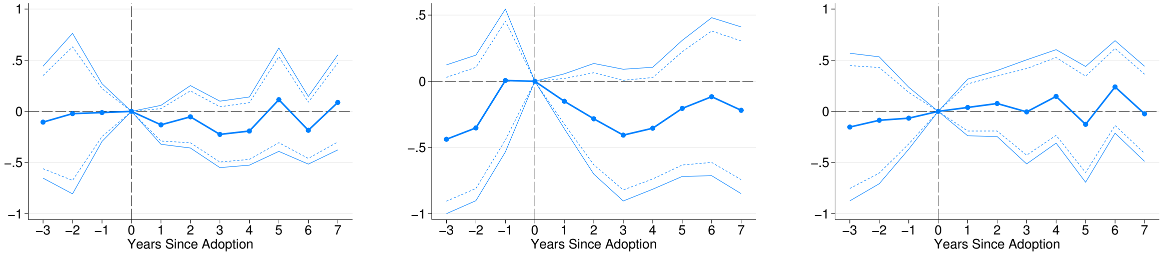
Direct Productivity Gains: Labor Productivity



Labor productivity ↑ 64%

Back to Direct Productivity Gains Results

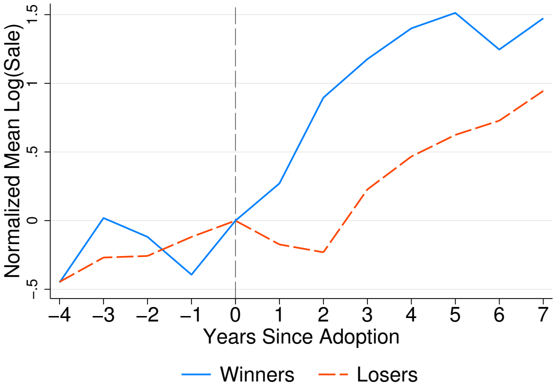
Direct Productivity Gains: Inputs



A. Log employment B. Log fixed assets C. Log fixed assets per worker

Back to Direct Productivity Gains Results

Raw Data Plot

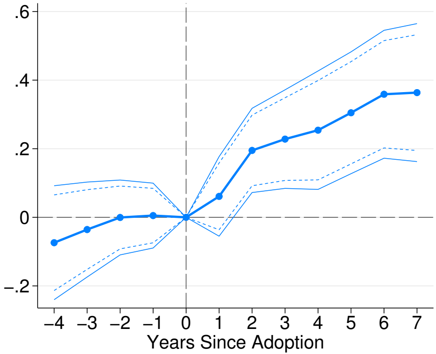


Normalized mean of log sales of winners & losers

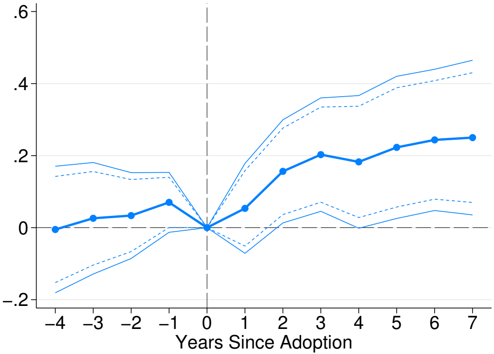
Back to Direct Productivity Gains Results

Standard TWFE Event Study

$$\log(\text{Sale}_{it}) = \sum_{\tau=-3}^{\tau=7} \beta_\tau \times \mathbb{1}[\text{Adopt}_{it}^{\tau}] + \mathbf{X}_{it}'\gamma + \delta_i + \delta_t + \epsilon_{it},$$



A. Log sales



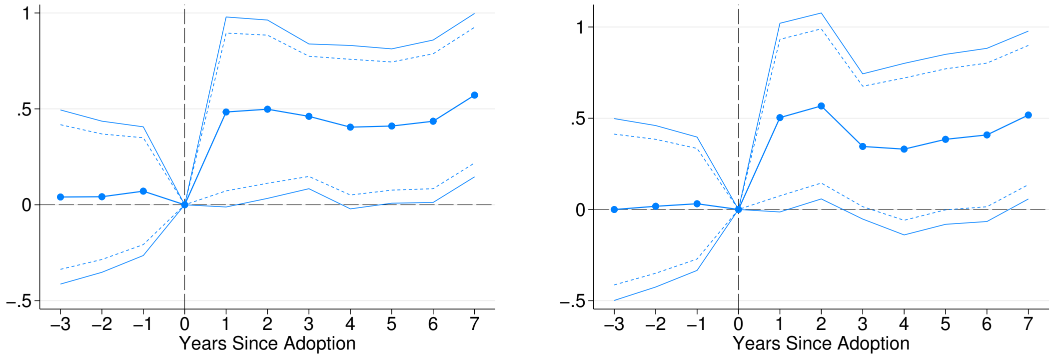
B. Log revenue TFP

Back to Direct Productivity Gains Results

Pair Time FEs

Regression Model

$$\log y_{ipt} = \sum_{\tau=-3}^{7} \beta_{\tau}^{diff} (D_{pt}^{\tau} \times \mathbb{1}[Adopt_{it}]) + \delta_i + \delta_{p\tau} + \epsilon_{ipt}$$



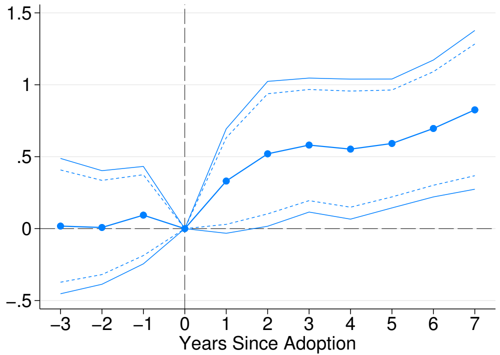
A. Log sale

B. Log revenue TFP

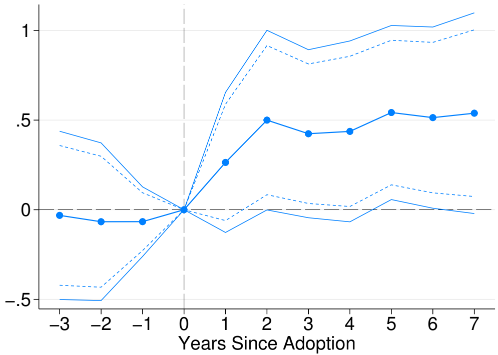
Back to Direct Productivity Gains Results

Different Matching

- Matching: Log asset, Asset growth between $t-1$ and t



A. Log sale



B. Log revenue TFP

Back to Direct Productivity Gains Results

Local Productivity Spillovers: Examples

Local Diffusion of Knowledge Wonil Machinery Work (Hot and cold rolling mill producer)

- A local firm adopted technology related to sophisticated 4-high nonreverse cold rolling mills
- One Wonil's engineer could obtain technical information indirectly from this local firm
- Wonil developed its own 4-high cold rolling mill

Labor Mobility and Learning Externality POSCO (Korea's largest integrated steel mill)

- The government heavily subsidized POSCO for the adoption of foreign technology
- Some of the engineers who left POSCO got jobs in local capital good producers
- These engineers helped these local firms produce capital equipment that POSCO used
  - (E.g.) equipment for treating water and collecting dust and a large magnetic crane

Back to Spillover Regression

Local Productivity Spillovers: Controls

Dep. Var.	log sales				
	(1)	(2)	(3)	(4)	(5)
Spill	4.39***	4.94***	4.23***	3.79**	4.07**
	(1.54)	(1.70)	(1.50)	(1.64)	(1.76)
ln(Spill-Sales)		✓			✓
ln(Input-MA)			✓		✓
Conglomerate FE				✓	✓
N	1079	1079	1079	1073	1073

Controls

$$\underbrace{\ln\left(\sum_{k\in nj/\{i\}}\left\{\frac{(1/dist_{ik})Sales_{kt}}{\sum_{k'\in nj/\{i\}}(1/dist_{ik'})}\right\}\right)}_{\text{Weighted average of sales}}, \qquad \underbrace{\ln\left(\sum_{j'}\sum_{k\in nj'/\{i\}}\gamma_j^{j'}(1/dist_{ik})Sales_{kt}\right)}_{\text{Market size due to local input sourcing}}$$

Back to Spillover Results

Local Productivity Spillovers: Revenue TFP

Dep. Var.	log revenue TFP				
	(1)	(2)	(3)	(4)	(5)
Spill	5.55***	5.34***	5.81***	5.41***	5.11**
	(1.84)	(1.62)	(2.08)	(1.78)	(1.92)
ln(Spill-Sales)		✓			✓
ln(Input-MA)			✓		✓
Conglomerate FE				✓	✓
N	344	344	344	292	292

- Interpretation:
  1. One std. spillover (0.33) ↑ → revenue TFP ↑ 18%
  2. (Semi-elasticity) probability of interacting with adopters ↑ 1pp → revenue TFP ↑ 5 - 5.8%

Back to Spillover Results

Local Productivity Spillovers: Full Sample Results

Dep.	log sales					log revenue TFP				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Spill	4.23***	4.45***	3.86***	3.72**	3.93***	4.75***	4.72***	4.45***	3.99**	3.44*
	(1.18)	(1.43)	(1.31)	(1.19)	(1.52)	(1.63)	(1.90)	(1.73)	(1.58)	(1.82)
$\mathbb{1}[Adopt]$	0.32**	0.26	0.32**	0.31**	0.25	0.15*	0.14	0.15*	0.14	0.12
	(0.15)	(0.20)	(0.15)	(0.15)	(0.19)	(0.09)	(0.10)	(0.09)	(0.09)	(0.10)
ln(Spill-Sales)		✓			✓		✓			✓
ln(Input-MA)			✓		✓			✓		✓
Conglomerate FE				✓	✓				✓	✓
N	1264	1259	1264	1264	1259	431	387	431	431	387

Back to Spillover Results

Local Productivity Spillovers: Spillover Defined at the Broader Level

$$\text{Spill}_{inj(t-h)} = \sum_{k \in N(n)j/\{i\}} \left\{ \frac{(1/dist_{ik})\mathbb{1}[\text{Adopt}_{k(t-h)}]}{\sum_{k' \in N(n)j/\{i\}} (1/dist_{ik'})} \right\}$$

	(1)	(2)	(3)	(4)	(5)
Spill	3.54**	4.12**	3.36*	3.51**	3.83**
	(1.69)	(1.78)	(1.73)	(1.61)	(1.63)
ln(Spill-Sales)		✓			✓
ln(Input-MA)			✓		✓
Conglomerate FE				✓	✓
N	1079	1079	1079	1073	1073

Back to Spillover Results

Local Productivity Spillovers: Alternative Spillover Measure

Alternative spillover measure: Weighted sum

$$\text{Sum-Spill}_{inj(t-h)} = \sum_{k \in nj/\{i\}} \left\{ (1/dist_{ik}) \mathbb{1}[\text{Adopt}_{k(t-h)}] \right\}$$

	(1)	(2)	(3)	(4)	(5)
Sum-Spill	0.15**	0.15*	0.15*	0.20***	0.20***
	(0.08)	(0.08)	(0.08)	(0.07)	(0.07)
ln(Spill-Sales)		✓			✓
ln(Input-MA)			✓		✓
Conglomerate FE				✓	✓
N	1079	1079	1079	1073	1073

- One std. spillover (1.21) ↑ → Sales 18–24% ↑

Back to Spillover Results

Complementarity: Other controls

Dep. Var.	$\mathbb{1}$[New Contract]				
	(1)	(2)	(3)	(4)	(5)
Spill	0.49***	0.49**	0.46***	0.49***	0.47***
	(0.18)	(0.19)	(0.15)	(0.18)	(0.15)
ln(Spill-Sales)		✓			✓
ln(Input-MA)			✓		✓
Conglomerate FE				✓	✓
N	2689	2689	2689	2688	2688

Controls

$$\underbrace{\ln\left(\sum_{k\in nj/\{i\}}\left\{\frac{(1/dist_{ik})\text{Sales}_{kt}}{\sum_{k'\in nj/\{i\}}(1/dist_{ik'})}\right\}\right)}_{\text{Weighted average of sales}}, \quad \underbrace{\ln\left(\sum_{j'}\sum_{k\in nj'/\{i\}}\gamma_j^{j'}(1/dist_{ik})\text{Sales}_{kt}\right)}_{\text{Market size due to local input sourcing}}$$

Back to Complementarity Results

Local Cross-Sector Productivity Spillovers

Regression Model   Overlapping long-difference   1971-1979, 1972-1980

$$\triangle y_{injt} = \beta^S \triangle \text{Spill}_{inj(t-4)} + \beta^S_{for} \underbrace{\left(\sum_{g \neq j} \gamma_j^g \triangle \text{Spill}_{ing(t-4)} \right)}_{\text{Forward spillover}} + \beta^S_{back} \underbrace{\left(\sum_{g \neq j} \gamma_g^j \triangle \text{Spill}_{ing(t-4)} \right)}_{\text{Backward spillover}} + \mathbf{X}'_{injt_0} \boldsymbol{\beta} + \triangle \delta_{njt} + \triangle \epsilon_{injt}.$$

- γ_j^g: Shares of sector g intermediate inputs used by sector j

Back to Spillover Results

Local Cross-Sector Productivity Spillovers

Dep. Var.	Log sales				
	(1)	(2)	(3)	(4)	(5)
Spill	4.11**	3.56**	4.61**	4.01**	3.85**
	(1.73)	(1.71)	(1.85)	(1.68)	(1.80)
Forward Spill (β^S_{for})	−0.35	0.32	−0.05	0.21	0.98
	(2.65)	(1.99)	(2.79)	(2.54)	(2.03)
Backward Spill (β^S_{back})	−6.58	−9.23	−5.42	−7.54	−9.52
	(11.38)	(7.78)	(12.60)	(11.25)	(8.42)
Conglomerate FE		✓			✓
ln(Spill-Sales)			✓		✓
ln(Input-MA)				✓	✓
N	1079	1073	1079	1079	1073

Back to Spillover Results

Labor Supply: Spatial Mobility

Preference

$$\prod_j C_{njt}^{\alpha_j}, \qquad \sum_j \alpha_j = 1$$

Household Utility

$$\mathcal{U}_{mn,t}^h = \underbrace{V_{nt}}_{\text{Amenity}} \times \underbrace{\frac{(1-\tau_t^w + \bar{\pi}_t^h)w_{nt}}{\prod_j (P_{njt})^{\alpha_j}}}_{\text{Real income}} \times \underbrace{d_{mn}}_{\text{Migration cost}} \times \underbrace{\epsilon_{nt}^h}_{\text{Idiosyncratic preference shock}}, \qquad \epsilon_{nt}^h \sim F(\epsilon) = \underbrace{exp(\epsilon^{-\nu})}_{\text{Fréchet}}$$

• V_n	:	Amenity	,	• w_{nt}	:	Wage	,	• P_{nt}	:	Price index
• τ_t^w	:	Labor tax	,	• $\bar{\pi}_t^h$	:	Dividend per share	,	• d_{mn}	:	Migration costs

Migration Shares

$$\mu_{mnt} = \frac{\left(V_{nt}\frac{(1-\tau_t^w+\bar{\pi}_t^h)w_{nt}}{P_{nt}} d_{mn}\right)^{\nu}}{\sum_{n'=1}^{N}\left(V_{n't}\frac{(1-\tau_t^w+\bar{\pi}_t^h)w_{n't}}{P_{n't}} d_{mn'}\right)^{\nu}}$$

Population Evolution

$$L_{nt} = \sum_{m\in\mathcal{N}} \mu_{mnt} L_{mt-1}.$$

Back to Full Quantitative Model   Back to Aggregate Welfare Gain

Adoption Subsidy

Adoption subsidy

- Input subsidy for adopters

$$\underbrace{(1 - s_t) \times [w_{nt} L_{it} + \sum_{k \in \mathcal{J}} P_{nkt} M_{it}^k]}_{\text{Total input expenditure of adopter } i}, \qquad 0 < s_t < 1$$

- Balanced government budget each period
- Financed by labor tax

Unit cost

$$\text{(Non-adopter)} \quad \frac{c_{njt}}{f(\lambda_{njt-1})\phi_{it}} \qquad\qquad \text{(Adopter)} \quad \frac{(1 - s_t)c_{njt}}{\eta f(\lambda_{njt-1})\phi_{it}}$$

- c_{njt}: Price of an input bundle

Back to Full Quantitative Model

A Firm's Maximization Problem

$$\pi_{it} = \max_{x_{it}, T_{it} \in \{0,1\}} \Bigg\{ \frac{1}{\sigma} \left(\frac{\sigma}{\sigma - 1} \left(\frac{1 - s_t}{\eta} \right)^{T_{it}} \frac{c_{njt}}{f(\lambda_{njt-1}) \phi_{it}} \right)^{1-\sigma} \sum_{m \in \mathcal{N}} \tau_{nmj}^{1-\sigma} P_{mjt}^{\sigma-1} E_{mjt}$$

$$+ x_{it} \left[\frac{1}{\sigma} \left(\frac{\sigma}{\sigma - 1} \left(\frac{1 - s_t}{\eta} \right)^{T_{it}} \frac{c_{njt}}{f(\lambda_{njt-1}) \phi_{it}} \right)^{1-\sigma} (\tau_{nj}^{x})^{1-\sigma} D_{jt}^{f} - c_{njt} F_j^{x} \right] - T_{it} c_{njt} F_j^{T} \Bigg\}$$

- Fixed adoption/export costs $\rightarrow$ Cutoff productivity of adoption/export
- Spillover: Dynamic complementarity in firms' adoption decisions
  1. $\uparrow \lambda_{njt-1}$ $\rightarrow$ $\uparrow$ firm scale in t $\rightarrow$ $\uparrow \lambda_{njt}$
  2. $\uparrow \lambda_{njt-1}$ $\rightarrow$ $\downarrow$ fixed adoption costs in t $(\downarrow c_{njt} F_j^{T})$ $\rightarrow$ $\uparrow \lambda_{njt}$

Back to Net Gains Back to Full Quantitative Model

Production

Final goods producer

$$Q_{njt} = \Bigg[\underbrace{\sum_{m \in \mathcal{N}} \left(\int_{\omega \in \Omega_{mj}} q_{it}(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right)}_{\text{Domestic varieties}} + \underbrace{\int_{\omega \in \Omega_j^f} q_{it}^f(\omega)^{\frac{\sigma-1}{\sigma}} d\omega}_{\text{Foreign varieties}} \Bigg]^{\frac{\sigma}{\sigma-1}}$$

- σ: Elasticity of substitution

Firms (Intermediate goods producer)

$$q_{it}(\omega) = z_{it}(\omega)(L_{it}(\omega))^{\gamma_j^L} \prod_{k \in \mathcal{J}} (M_{it}^k(\omega))^{\gamma_j^k}, \qquad \gamma_j^L + \sum_{k \in \mathcal{J}} \gamma_j^k = 1$$

Back to Full Quantitative Model

Distributional Assumption: Bounded Pareto

Firm productivity

$$z_{it} = \eta^{T_{it}} \times f(\lambda_{njt-1}) \times \underbrace{\phi_{it}}_{\text{Exogenous productivity}}$$

Distributional Assumptions

- Bounded Pareto (Chaney, 2008; Helpman et al., 2008)

$$\phi_{it} \sim \frac{1 - (\phi_{it}/\bar{\phi}^{min}_{njt})^{-\theta}}{1 - (\bar{\phi}^{max}_{njt}/\bar{\phi}^{min}_{njt})^{-\theta}}$$

  - $\bar{\phi}^{min}_{njt}, \bar{\phi}^{max}_{njt}$: Lower and upper bounds of support , - θ: Shape parameter

- Three parameters: $\kappa = (\phi^{max}_{njt}/\phi^{min}_{njt})$, ϕ^{min}_{njt}, θ
  - ϕ^{min}_{njt}: Natural advantage

Back to Full Quantitative Model

Microfoundation: Local Diffusion of Non-rivalrous Idea

Local Diffusion of Non-rivalrous Idea

- A firm chooses innovation level a_{it} each period, which increases productivity (Desmet and Rossi-Hansberg, 2014)
- Costs of innovation in t decreases in adopter shares in the previous period $t-1$
- Larger adopter shares in the previous period increases the overall level of innovation in a local area.

A Firm's Maximization Problem

$$\pi_{it} = \max_{T_{it}\in\{0,1\},a_{it}\in[0,\infty)} \left\{ \frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\frac{w_{nt}}{\tilde{\eta}^{T_{it}} a_{it}^{\gamma_1}\tilde{\phi}_{it}}\right)^{1-\sigma} P_t^{\sigma-1}E_t - P_t T_{it} F^T - \underbrace{P_t a_{it}^{\alpha_1} g(\lambda_{nt-1}) B_t}_{\text{Innovation cost}} \right\}$$

$$= \max_{T_{it}\in\{0,1\}} \left\{ \frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\frac{w_{nt}}{(\bar{C}_{nt}^1)^{\gamma_1} \underbrace{g(\lambda_{nt-1})^{\frac{-1}{\alpha_1-1-\gamma_1(\sigma-1)}}}_{=f(\lambda_{nt-1})} \underbrace{(\tilde{\eta}^{\frac{\alpha_1-\sigma-\gamma_1(\sigma-1)}{\alpha_1-1-\gamma_1(\sigma-1)}})}_{=\eta}{}^{T_{it}} \underbrace{\tilde{\phi}_{it}^{\frac{\alpha_1-\sigma-\gamma_1(\sigma-1)}{\alpha_1-1-\gamma_1(\sigma-1)}}}_{=\phi_{it}}}\right)^{1-\sigma} P_t^{\sigma-1}E_t - P_t T_{it} F^T \right\}$$

• a_{it}: : Innovation level	• $\tilde{\phi}_{it}$: Exogenous productivity

Back to Spillover

Microfoundation: Learning Externality and Labor Mobility

Set-up

- *Demographics*: (1) Production worker, (2) Engineers, (3) Firm owners
- *Matching:*
  - Firm owners can produce only when matched with engineers.
  - One-to-one random matching each period (Acemoglu, 1996)
  - Share profits by Nash bargaining.
- *Learning Externality*
  - Engineers: Two-period OLG. Only work when in the adulthood
  - If an adult works in an adopting firm, her child obtains higher engineering skills when she becomes an adult in the next period.

A Firm's Profit Maximization Problem

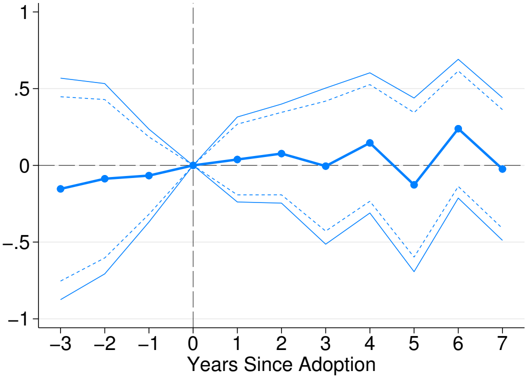
$$\pi_{it} = \max_{T_{it}\in\{0,1\}} (1-\tilde{\beta}) \left\{ \lambda_{nt-1} \frac{1}{\sigma} \left(\frac{\sigma}{\sigma-1} \frac{w_{nt}}{\tilde{\eta}^{T_{it}} \gamma_1 \tilde{\phi}_{it}} \right)^{1-\sigma} P_t^{\sigma-1} E_t + (1-\lambda_{nt-1}) \frac{1}{\sigma} \left(\frac{\sigma}{\sigma-1} \frac{w_{nt}}{\tilde{\eta}^{T_{it}} \tilde{\phi}_{it}} \right)^{1-\sigma} P_t^{\sigma-1} E_t - w_{nt} F^T T_{it} \right\}$$

- Maximize expected profits
- Complementarity between engineering skills and gains from adoption:
  - Engineers with higher skill $\uparrow \rightarrow$ Adoption $\uparrow$

Back to Spillover

Empirical Evidence on Hicks-Neutrality

Dependent Variable: *Capital / Emp*



"Winners vs. Losers" Research Design

Back to Spillover

Adoption Productivity Cutoff

Adoption Productivity Cutoff

$$\bar{\phi}^T_{njt} = \left(\frac{\mu c_{njt}(\sigma w_{nt} F^T_j)^{\frac{1}{\sigma-1}}}{(\eta/(1-s_t))^{\sigma-1} - 1)^{\frac{1}{\sigma-1}} f(\lambda_{njt-1}) \left(\sum_m \tau_{nmj} P_{mjt} E_{mjt}^{\frac{1}{\sigma-1}} + \tau_x D_{fj,t}^{\frac{1}{\sigma-1}} \right)} \right)$$

Adoption Probability

$$\lambda_{njt} = \mathbb{P}[\phi \geq \bar{\phi}^T_{njt}] = \frac{(\bar{\phi}^T_{njt}/\phi^{min}_{njt})^{-\theta} - \kappa^{-\theta}}{1 - \kappa^{-\theta}}$$

(Partial) Comparative Statistics

- (Subsidy) $s_t \uparrow \quad \rightarrow \quad \lambda_{njt} \uparrow$
- (Market size) $(\sum_m \tau_{nmj} P_{mjt} E_{mjt}^{\frac{1}{\sigma-1}} + \tau_x D_{fj,t}^{\frac{1}{\sigma-1}}) \uparrow \quad \rightarrow \quad \lambda_{njt} \uparrow$
- (Spillover) $\lambda_{njt-1} \uparrow \quad \rightarrow \quad \lambda_{njt} \uparrow$

Back to Profit Maximization

Export Productivity Cutoff

Export Productivity Cutoff

$$\bar{\phi}^x_{njt} = \left(\frac{\mu c_{njt} (\sigma w_{nt} F^x_j)^{\frac{1}{\sigma-1}}}{f(\lambda_{njt-1}) \tau^x_{nj} D^{\frac{1}{\sigma-1}}_{fj,t}} \right)$$

Export Probability

$$\lambda^x_{njt} = \mathbb{P}[\phi \geq \bar{\phi}^x_{njt}] = \frac{(\bar{\phi}^x_{njt} / \phi^{min}_{njt})^{-\theta} - \kappa^{-\theta}}{1 - \kappa^{-\theta}}$$

Back to Full Quantitative Model

Aggregate Domestic Sales

$$R^d_{njt} = \underbrace{M_{nj}}_{\substack{\text{Mass of}\\ \text{firms}}} \times \underbrace{(\mu c_{njt})^{1-\sigma}}_{\text{Input bundle costs}} \times \underbrace{(\bar{\phi}^{avg}_{njt})^{\sigma-1}}_{\substack{\text{Average productivity}\\ \text{inclusive of subsidy}}} \times \underbrace{\sum_{m\in\mathcal{N}} \tau^{1-\sigma}_{nmj} P^{1-\sigma}_{mjt} E_{mjt}}_{\substack{\text{Firm domestic}\\ \text{market access}}}$$

where

$$\bar{\phi}^{avg}_{njt} = \bar{\phi}^{avg}\Big(\underbrace{\lambda_{njt-1}}_{\text{spillover}\uparrow}, \underbrace{\lambda_{njt}}_{\substack{\text{direct}\\ \text{productivity}\\ \text{gains}\uparrow}}, \underbrace{s_t}_{\text{subsidy}\uparrow}, \underbrace{\phi^{min}_{njt}}_{\substack{\text{natural}\\ \text{advantage}\uparrow}} \Big)$$

$$= \frac{\theta f(\lambda_{njt-1})(\phi^{min}_{njt})^{\sigma-1}}{\tilde{\theta}(1-\kappa^{-\theta})} \left\{ \left(\left(\frac{\eta}{s_{njt}} \right)^{\sigma-1} - 1 \right) (\tilde{\lambda}_{njt})^{\frac{\tilde{\theta}}{\theta}} + \left(1 - \left(\frac{\eta}{s_{njt}} \right)^{\sigma-1} \kappa^{-\tilde{\theta}} \right) \right\}$$

Back to Full Quantitative Model

Aggregate Export

$$R^x_{njt} = \underbrace{M^x_{njt}}_{\substack{\text{Mass of}\\\text{exporters}}} \times \underbrace{(\mu c_{njt})^{1-\sigma}}_{\text{Input bundle costs}} \times \underbrace{(\bar{\phi}^{x,avg}_{njt})^{\sigma-1}}_{\substack{\text{Exporters'}\\\text{average productivity}\\\text{inclusive of subsidy}}} \times \underbrace{(\tau^x_{nj})^{1-\sigma} D^f_{jt}}_{\substack{\text{Firm foreign}\\\text{market access}}}$$

where

$$\bar{\phi}^{x,avg}_{njt} = \bar{\phi}^{x,avg}\Big(\underbrace{\lambda_{njt-1}}_{\text{spillover}\uparrow}, \underbrace{\lambda_{njt}}_{\substack{\text{direct}\\\text{productivity}\\\text{gains}\uparrow}}, \underbrace{s_t}_{\text{subsidy}\uparrow}, \underbrace{\phi^{min}_{njt}}_{\substack{\text{natural}\\\text{advantage}\uparrow}}, \underbrace{\lambda^x_{njt}}_{\text{Selection}\downarrow} \Big)$$

$$= \frac{\theta f(\lambda_{njt-1})(\phi^{min}_{njt})^{\sigma-1}}{\tilde{\theta}(1-\kappa^{-\theta})} \frac{(\tilde{\lambda}^x_{njt})^{\frac{\tilde{\theta}}{\theta}}}{\lambda^x_{njt}} \left\{ \left(\left(\frac{\eta}{s_{njt}} \right)^{\sigma-1} - 1 \right) \left(\frac{\tilde{\lambda}_{njt}}{\tilde{\lambda}^x_{njt}} \right)^{\frac{\tilde{\theta}}{\theta}} + \left(1 - \left(\frac{\eta}{s_{njt}} \right)^{\sigma-1} \kappa^{-\tilde{\theta}} (\tilde{\lambda}^x_{njt})^{-\frac{\tilde{\theta}}{\theta}} \right) \right\}$$

Back to Full Quantitative Model

Price index

$$P_{njt}^{1-\sigma} = \sum_{m \in \mathcal{N}} \left[M_{mj} \underbrace{\left(\mu \tau_{mnj} c_{mjt}\right)^{1-\sigma}}_{\text{Unit cost}} \times \underbrace{\left(\bar{\phi}_{mjt}^{avg}\right)^{\sigma-1}}_{\substack{\text{Average productivity} \\ \text{inclusive of subsidy}}} \right] + \underbrace{\left(\tau_{nj}^{x} c_{jt}^{f}\right)^{1-\sigma}}_{\substack{\text{Consumer foreign} \\ \text{market access}}},$$

where

$$\bar{\phi}_{njt}^{avg} = \bar{\phi}^{avg}\Big(\underbrace{\lambda_{njt-1}}_{\text{spillover}\uparrow}, \underbrace{\lambda_{njt}}_{\substack{\text{direct} \\ \text{productivity} \\ \text{gains}\uparrow}}, \underbrace{s_t}_{\text{subsidy}\uparrow}, \underbrace{\phi_{njt}^{min}}_{\substack{\text{natural} \\ \text{advantage}\uparrow}} \Big)$$

$$= \frac{\theta f(\lambda_{njt-1})(\phi_{njt}^{min})^{\sigma-1}}{\tilde{\theta}(1-\kappa^{-\theta})} \left\{ \left(\left(\frac{\eta}{s_{njt}} \right)^{\sigma-1} - 1 \right) (\tilde{\lambda}_{njt})^{\frac{\tilde{\theta}}{\theta}} + \left(1 - \left(\frac{\eta}{s_{njt}} \right)^{\sigma-1} \kappa^{-\tilde{\theta}} \right) \right\}$$

Back to Full Quantitative Model

Trade Shares

Domestic trade share

$$\pi_{mnjt} = \frac{(\tau_{mnj} c_{mjt} / \bar{\phi}^{avg}_{mjt})^{1-\sigma}}{P^{1-\sigma}_{njt}}.$$

Foreign import trade share

$$\pi^{f}_{njt} = \frac{(\tau^{x}_{nj} c^{f}_{jt})^{1-\sigma}}{P^{1-\sigma}_{njt}}.$$

Back to Full Quantitative Model

Institutional Background on Labor Tax

Kim and Topel (1995)

- Restricted any firms' nominal wage growth to be below 80% of the sum of inflation and aggregate productivity growth
- Emergency provisions were enacted in 1971 which prohibited labor union activities.

Back to Full Quantitative Model

Dynamic Equilibrium

Given initial shares of adopters $\{\lambda_{njt_0}\}$ and the path of the geographic fundamentals $\mathbf{\Psi}_t$, a dynamic equilibrium is a path of

- wages $\{w_{nt}\}$,
- price indices $\{P_{njt}\}$
- population $\{L_{nt}\}$
- a share of adopters $\{\lambda_{njt}\}$
- a set of functions $\{p_{it}(\omega), q_{it}(\omega), T_{it}(\omega), x_{it}(\omega), p_{it}(\omega)^x, q_{it}(\omega)^x\}$

- **(Static Equilibrium Allocation)** for each period t,

  (i) firms maximize profits;
  (ii) households maximize utility by making consumption decisions;
  (iii) labor markets clear;
  (iv) goods markets clear;
  (v) trade is balanced;
  (vi) the government budget is balanced.

- **(Law of Motion of Population)** (vii) $\{L_{nt}\}$ follows the law of motion;
- **(Law of Motion of a Mass of Adopters)** (viii) $\{\lambda_{njt}\}_{j\in\mathcal{J}^T}$ follows the law of motion.

Back to Full Quantitative Model

Analytical Results: Multiple Steady States

(Period-by-period) Short-run equilibrium

- $\lambda_t^* = \min\{\hat{\lambda}_t, 1\}$ where

$$\hat{\lambda}_t = \Bigg[\underbrace{\frac{(\eta^{\sigma-1} - 1)}{\sigma F^T} \times \left[(\eta^{\sigma-1} - 1)(\hat{\lambda}_t)^{\frac{\theta-(\sigma-1)}{\theta}} + 1\right]^{\frac{2-\sigma}{\sigma-1}} \times f(\lambda_{t-1}^*)}_{\text{Marginal adopter's net gains from adoption}} \Bigg]^{\frac{\theta}{\sigma-1}}, \qquad f(\lambda) = exp(\delta\lambda)$$

- Dynamic complementarity : Marginal adopter's net gains from adoption increases in λ_{t-1}^*

Back to Net Gains

Analytical Results: Multiple Steady States

(Period-by-period) Short-run equilibrium

- $\lambda_t^* = \min\{\hat{\lambda}_t, 1\}$ where

$$\hat{\lambda}_t = \Bigg[\underbrace{\frac{(\eta^{\sigma-1}-1)}{\sigma F^T} \times \left[(\eta^{\sigma-1}-1)(\hat{\lambda}_t)^{\frac{\theta-(\sigma-1)}{\theta}}+1\right]^{\frac{2-\sigma}{\sigma-1}} \times f(\lambda_{t-1}^*)}_{\text{Marginal adopter's net gains from adoption}}\Bigg]^{\frac{\theta}{\sigma-1}}, \qquad f(\lambda) = exp(\delta\lambda)$$

- Dynamic complementarity : Marginal adopter's net gains from adoption increases in λ_{t-1}^*

Steady states

- $\lambda^* = \lambda_t^* = \lambda_{t-1}^*$

Back to Net Gains

Analytical Results: Multiple Steady States

(Period-by-period) Short-run equilibrium

- $\lambda_t^* = \min\{\hat{\lambda}_t, 1\}$ where

$$\hat{\lambda}_t = \Bigg[\underbrace{\frac{(\eta^{\sigma-1} - 1)}{\sigma F^T} \times \left[(\eta^{\sigma-1} - 1)(\hat{\lambda}_t)^{\frac{\theta-(\sigma-1)}{\theta}} + 1 \right]^{\frac{2-\sigma}{\sigma-1}} \times f(\lambda_{t-1}^*)}_{\text{Marginal adopter's net gains from adoption}} \Bigg]^{\frac{\theta}{\sigma-1}}, \qquad f(\lambda) = exp(\delta\lambda)$$

- Dynamic complementarity : Marginal adopter's net gains from adoption increases in λ_{t-1}^*

Steady states

- $\lambda^* = \lambda_t^* = \lambda_{t-1}^*$

Properties

1. Given initial λ_0, $\exists$ a unique equilibrium path
   - For each t, short-run equilibrium is unique (no contemporaneous spillover)
2. η (direct effect) $\uparrow \quad \rightarrow \quad \lambda_t^* \uparrow$
3. δ (spillover) $\uparrow \quad \rightarrow \quad \lambda_t^* \uparrow$

Back to Net Gains

Analytical Results: Technical Assumptions

Simpler environment

(1) Unbounded Pareto with normalized lower bound

(2) One region, one sector

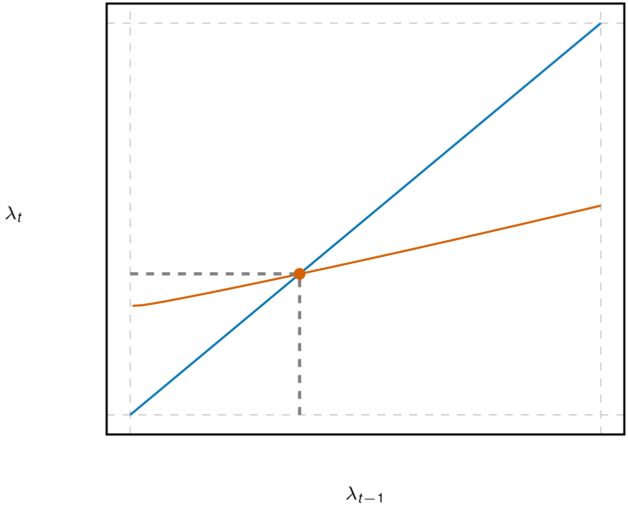
(3) Firm mass normalized to be 1 ($M = 1$)

(4) Fixed adoption cost F^T in units of final goods (Dynamic complementarity)

(5) Elasticity of substitution $\sigma > 2$ (Uniqueness) (Buera et al., 2021)

Back to Net Gains

Temporary adoption subsidies can have permanent effects only when multiple steady states exist

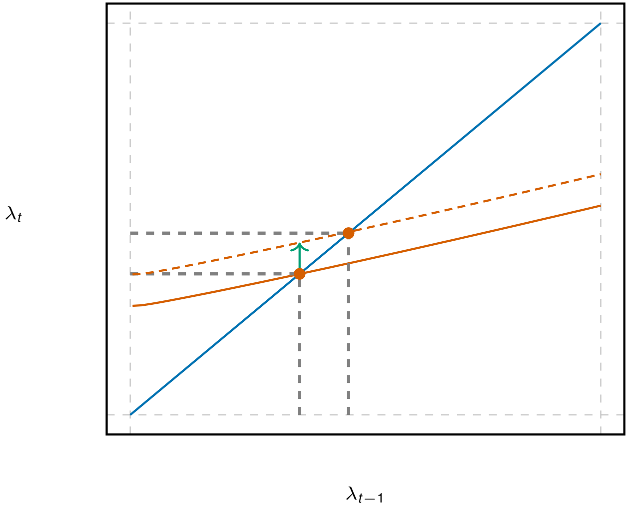


Temporary subsidies for $t \in \{t_0, \ldots, t_1\}$

1. Initially at the steady state of the original short-run equilibrium condition

Back to Multiple Steady States | Back to Role of Temporary Subsidies

Temporary adoption subsidies can have permanent effects only when multiple steady states exist

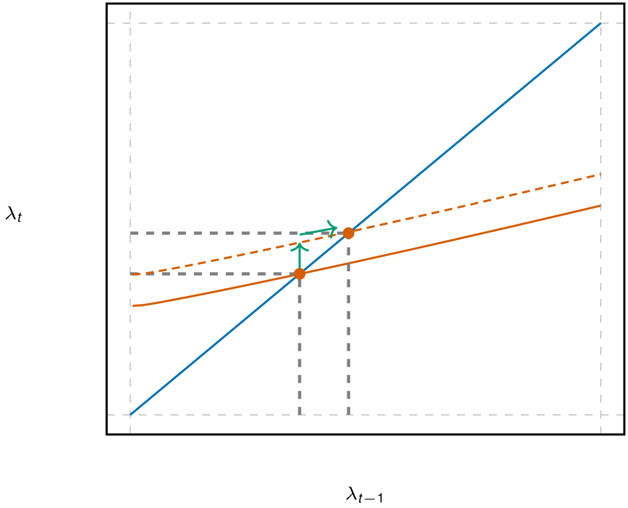


Temporary subsidies for $t \in \{t_0, \ldots, t_1\}$

1. Initially at the steady state of the original short-run equilibrium condition
2. Start of the temporary subsidies: Jump to the new short-run equilibrium condition

Back to Multiple Steady States Back to Role of Temporary Subsidies

Temporary adoption subsidies can have permanent effects only when multiple steady states exist

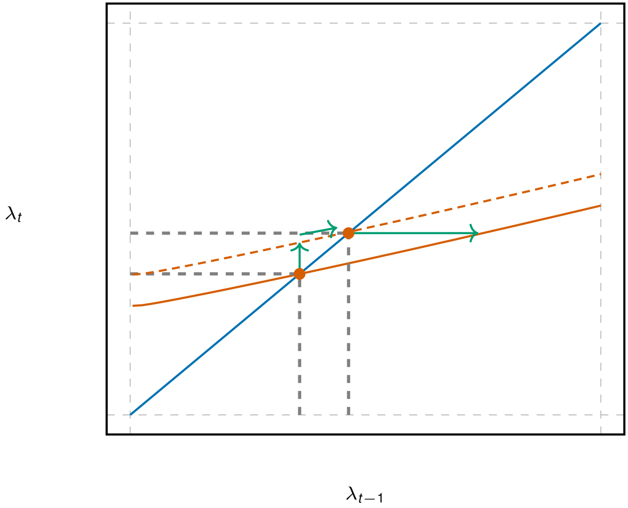


Temporary subsidies for $t \in \{t_0, \ldots, t_1\}$

1. Initially at the steady state of the original short-run equilibrium condition
2. Start of the temporary subsidies: Jump to the new short-run equilibrium condition
3. Converge to a new steady-state

Back to Multiple Steady States Back to Role of Temporary Subsidies

Temporary adoption subsidies can have permanent effects only when multiple steady states exist

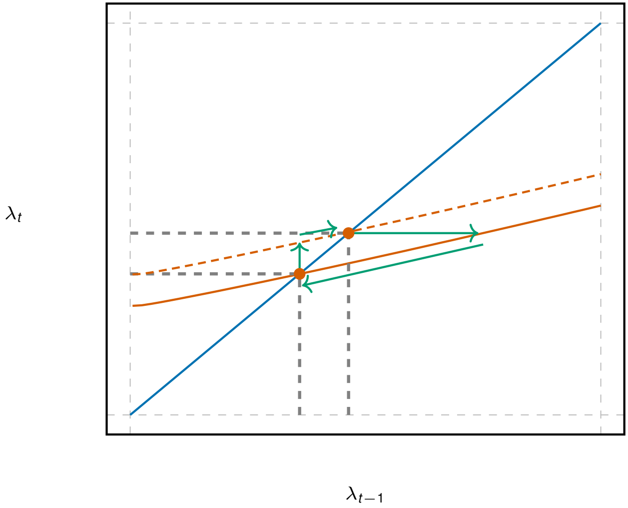


Temporary subsidies for $t \in \{t_0, \ldots, t_1\}$

1. Initially at the steady state of the original short-run equilibrium condition
2. Start of the temporary subsidies: Jump to the new short-run equilibrium condition
3. Converge to a new steady-state
4. End of the temporary subsidies: Shift right to the original short-run equilibrium condition

Back to Multiple Steady States | Back to Role of Temporary Subsidies

Temporary adoption subsidies can have permanent effects only when multiple steady states exist



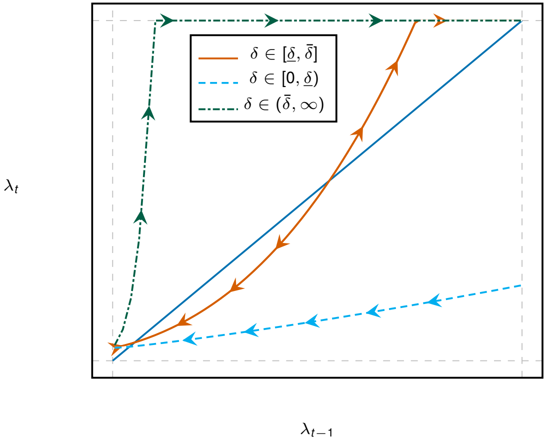
Temporary subsidies for $t \in \{t_0, \ldots, t_1\}$

1. Initially at the steady state of the original short-run equilibrium condition
2. Start of the temporary subsidies: Jump to the new short-run equilibrium condition
3. Converge to a new steady-state
4. End of the temporary subsidies: Shift right to the original short-run equilibrium condition
5. Converge to the original steady-state

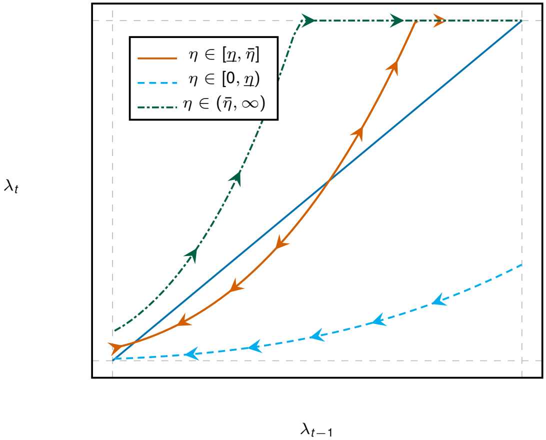
Back to Multiple Steady States Back to Role of Temporary Subsidies

Comparative Statistics (δ and η)

- Multiple steady states arise when the direct effects and the spillover are not too strong or not too weak.
  - $\exists$ intervals $[\underline{\delta}, \bar{\delta}]$ and $[\underline{\eta}, \bar{\eta}]$ such that multiple steady states arise only for $\delta \in [\underline{\delta}, \bar{\delta}]$ and $\eta \in [\underline{\eta}, \bar{\eta}]$



δ (Spillover)



η (Direct Productivity Gains)

Back to Multiple Steady States Back to Role of Temporary Subsidies

Identification of Subsidies

Subsidy Plan

$$s_{njt} = \begin{cases} \bar{s} & \text{if} \quad t \in \{1976, 1980\}, \quad \forall n \in \mathcal{N}, \quad \forall j \in \mathcal{J}^T \cap \mathcal{J}^{policy} \\ 0 & \text{otherwise} \end{cases}$$

Identifying moment

- Assumptions: (i) Unbounded Pareto; (ii) Free trade; and (iii) Symmetry $j \in \mathcal{J}^T$
- Regression:

$$\underbrace{\ln \lambda_{njt} - \theta\delta\lambda_{njt-1}}_{\substack{\text{Shares of adopters} \\ \text{net of spillovers}}} = \underbrace{\beta^{policy}}_{\substack{\text{Identifying} \\ \text{moments}}} \times D^{policy}_{jt} + \delta_{nt} + \epsilon_{njt}, \qquad \forall j \in \mathcal{J}^T$$

  - λ_{njt}: shares of adopters
  - θ: Pareto shape parameter
- Given values of η, δ, σ, and θ, $\hat{\beta}^{policy}$ uniquely identifies $\bar{s}$

$$\hat{\beta}^{policy} \quad \xrightarrow{p} \quad \beta^{policy} = \frac{\theta}{\sigma - 1}\left[\ln\left(\left(\frac{\eta}{1-\bar{s}}\right)^{\sigma-1} - 1\right) - \ln(\eta^{\sigma-1} - 1)\right],$$

Back to Calibration Strategy

External Calibration

Objects

$$\boldsymbol{\Theta}^E = \{\eta, \delta, \theta, \sigma, \gamma_j^k, \gamma_j^L, \tau_{nmj}, \tau_{nj}^x, \nu, \zeta, \alpha_j\}$$

Reduced-Form Estimates

• *(Direct productivity gains)*	$\eta = exp(0.51/(\sigma - 1))$	"Winners vs. losers" research design
• *(Spillover)*	$\delta = 4.5/(\sigma - 1)$	Spillover estimates

Standard in the Literature

• *(Elasticity of substitution)*	$\sigma = 3$	Broda and Weinstein (2008)
• *(Pareto shape)*	$\theta = 1.05(\sigma - 1)$	Axtell (2001)
• *(Internal trade costs)*	$\xi = 1.29/(\sigma - 1)$	Monte et al. (2018)
$\tau_{nmj} = dist_{nm}^{\xi}$		
• *(International trade Costs)*	$dport_n^{\xi_j}$	Distance to the closest port
$\tau_{nj}^x = dport_n^{\xi_j} \times \bar{\tau}^x$	$\bar{\tau}^x = 1.7$	Anderson and van Wincoop (2004)
• *(Migration elasticity)*	$\nu = 2$	Peters (2020)
• *(Migration costs)*	$\zeta = 1.38/\nu$	Gravity estimates
$d_{nm} = dist_{nm}^{\zeta}$		
• *(Firm mass)*	M_{nj}	Initial value-added shares, Chaney (2008)

Back to Calibration Strategy

Method of Moments

Objects

$$\boldsymbol{\Theta}^M = \{\kappa, F_j^T, F_j^x\}, \qquad \boldsymbol{\Psi}_t = \{\phi_{njt}^{min}, V_{nt}, D_{jt}^f, c_{jt}^f\}, \qquad \mathbf{s}_t$$

Method of moments

$$\{\hat{\boldsymbol{\Theta}}^M, \hat{\mathbf{s}}_t\} \equiv \arg\min_{\boldsymbol{\Theta}^M, \mathbf{s}_t} \underbrace{(\bar{\mathbf{m}} - \mathbf{m}(\boldsymbol{\Theta}^M, \boldsymbol{\Psi}_t, \mathbf{s}_t))'\mathbf{W}(\bar{\mathbf{m}} - \mathbf{m}(\boldsymbol{\Theta}^M, \boldsymbol{\Psi}_t, \mathbf{s}_t))}_{\text{Micro moments}} \quad \text{s.t.} \quad \underbrace{\mathbf{C}(\boldsymbol{\Theta}^M, \boldsymbol{\Psi}_t, \mathbf{s}_t) = \mathbf{C}_t}_{\text{Aggregate data}}$$

Intuition for identification

- Aggregate data — Average productivity (model inversion)
- Micro moments — Technology adoption and subsidy components of average productivity

Micro moments

- *(Fixed adoption cost)* — $F_j^T = 0.28$ — Shares of adopters in 1972
- *(Fixed export cost)* — $F_j^x = 0.06, 0.05$ — Shares of exporters in 1972
- *(Pareto upper bound)* — $\kappa = \phi_{njt}^{max} / \phi_{njt}^{min} = 4.42$ — Share of zero adoption regions in 1972
- *(Subsidy rate)* — $\bar{s} = 0.11$ — Identifying moment

Aggregate data

Exactly fitted to region-sector data in 1972, 1976, 1980

- *(Natural advantage)* — ϕ_{njt}^{min} — Gross output
- *(Amenity)* — V_{nt} — Population
- *(Foreign demands, import costs)* — D_{jt}^f, c_{jt}^f — Aggregate export and import shares

Back to Calibration Strategy

Model Fit

Moment	Model	Data
Identifying moment $\hat{\beta}^{policy}$	0.65	0.83
med. shares of exporters in 1972, light mfg.	0.22	0.21
med. shares of exporters in 1972, heavy mfg.	0.14	0.18
med. shares of adopters in 1972	0.06	0.07
med. shares of adopters in 1982	0.12	0.18
Share of zero adoption regions in 1972	0.59	0.53
Share of zero adoption regions in 1982	0.83	0.93

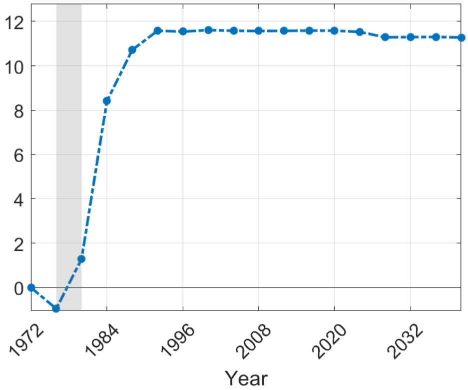
Back to Calibration Strategy

If subsidies had not been provided, aggregate welfare would have been 10% lower.

$$\underbrace{U_t^{agg} = \sum_{n \in \mathcal{N}} \frac{L_{nt-1}}{L} U_{nt}}_{\text{Aggregate welfare}} \quad \text{where} \quad \underbrace{U_{nt} = \mathbb{E}\left[\max_m \left\{\mathcal{U}_{mn,t}^h(\epsilon_{nt}^h)\right\}\right]}_{\text{Regional welfare}} = \left[\sum_{m \in \mathcal{N}} \left(\underbrace{V_{nt}}_{\text{Amenity}} \times \underbrace{\frac{(1 - \tau_t^w + \bar{\pi}_t^h) w_{nt}}{P_{nt}}}_{\text{Real income}} \times \underbrace{d_{mn}}_{\text{Migration cost}} \right)^{\nu}\right]^{\frac{1}{\nu}}$$

Regional Welfare Gain | Preference & Labor Mobility | Back to Quantitative Results

If subsidies had not been provided, aggregate welfare would have been 10% lower.



$$100 \times \left(U_t^{agg,\text{subsidy}} / U_t^{agg,\text{no subsidy}} - 1\right)$$

Regional Welfare Gain | Preference & Labor Mobility | Back to Quantitative Results

Amplifying Factors: Complementarity between Firm Scale and Gains from Adoption

Roundabout production

No Roundabout Production

- Mechanism : Cost and demand linkages (Krugman and Venables, 1995)
- Counterfactual : No roundabout production $\rightarrow$ Effects of the policy $\downarrow$ (No multiple steady states)

Foreign market size

Lower Foreign Market Size

- Mechanism : Complementarity between adoption and export (Lileeva and Trefler, 2010; Bustos, 2011)
- Counterfactual : Foreign market size $\downarrow$ $\rightarrow$ Effects of the policy $\downarrow$

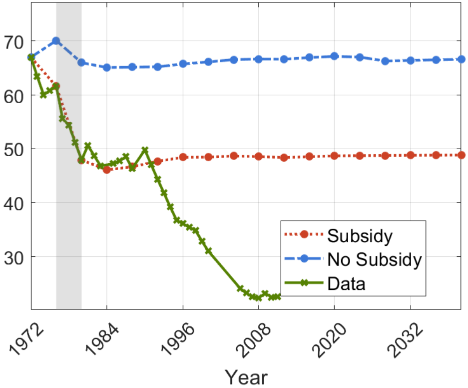
Migration costs

Higher Migration Costs

- Mechanism : Migration to regions with higher shares of adopters $\rightarrow$ Costs of production $\downarrow$
- Counterfactual : Migration costs $\uparrow$ (No migration) $\rightarrow$ Effects of the policy $\downarrow$

Back to Quantitative Results | Comparative Statistics: No Spillover | Non-Targeted Moments: Heavy Mfg. Regional Distribution | Regional Productivity Gains

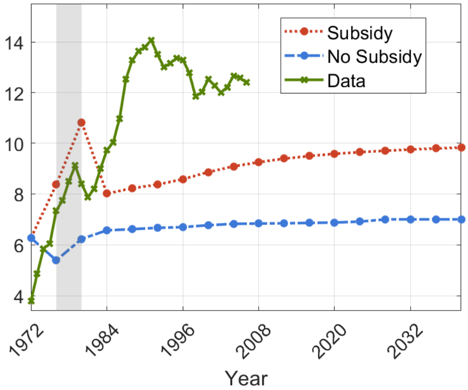
If subsidies had not been provided, the light mfg. export share would have been 20% permanently higher.



Light mfg. export share (%)

Back to Quantitative Results

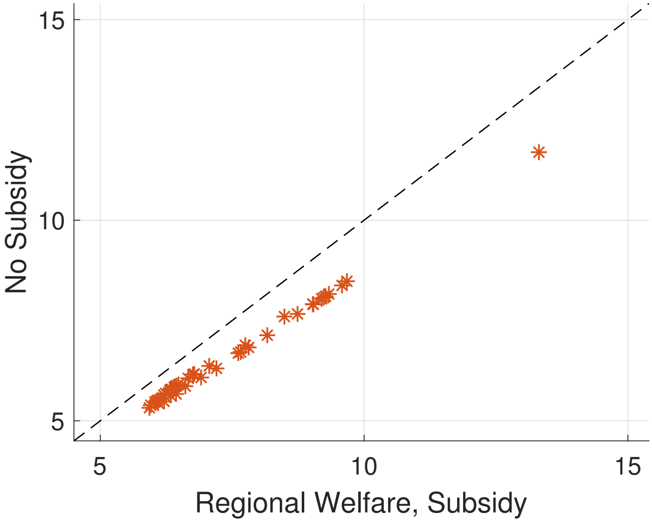
Heavy Mfg. Employment Share



Heavy mfg. emp. share (%)

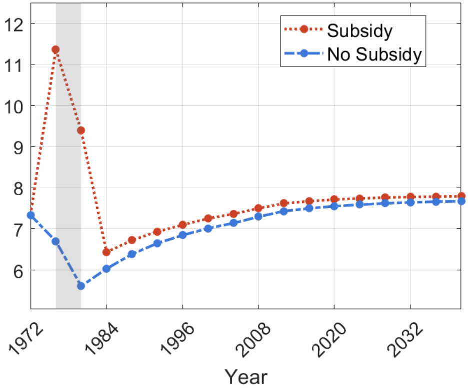
Back to Quantitative Results

Regional Welfare Gain

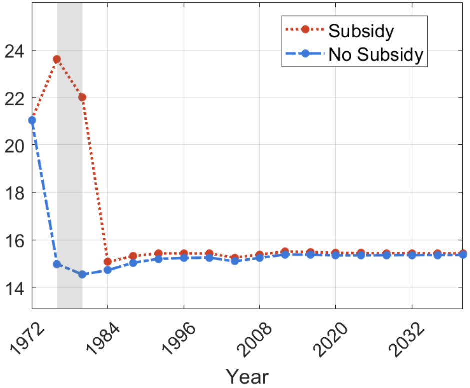


Back to Aggregate Welfare Gain

No Roundabout Production Structure



A. Heavy mfg. GDP share (%)

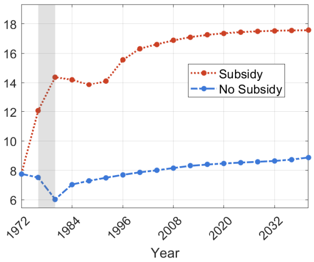


B.Heavy mfg. export share (%)

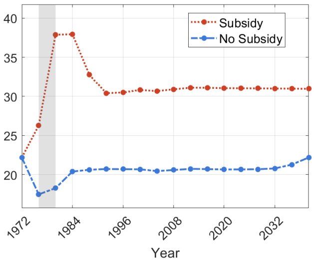
Go Back to Additional Results

Lower Foreign Market Size

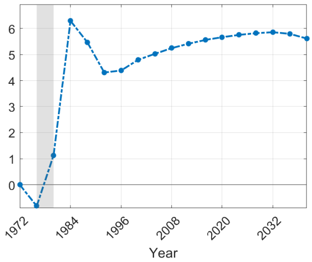
- $\iota \times D^{f}_{heavy,t}$, $\quad \iota < 1, \quad t \in \{1972, 1976, 1980\}$
- ι: Export shares of heavy mfg. in 1972 $\quad 22\% \rightarrow 6.6\%$



A. Heavy mfg. GDP share (%)



B. Heavy mfg. export share (%)

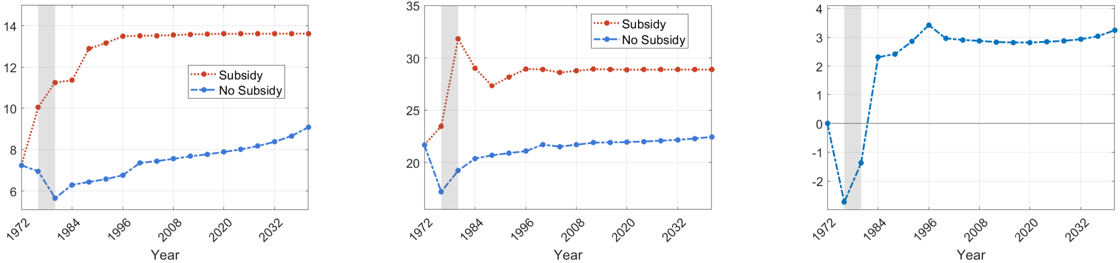


C. Agg. Welfare Gain (%)

Go Back to Additional Results

Higher Migration Costs

- Migration cost $d_{mn} \uparrow$: No migration



A. Heavy mfg. GDP share (%)   B. Heavy mfg. export share (%)   C. Agg. Welfare Gain (%)

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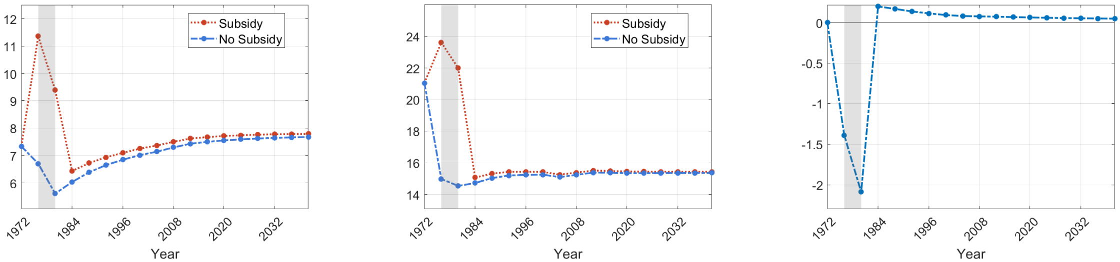
No Spillover

- No Spillover $\delta = 0$



A. Heavy mfg. GDP share (%) B. Heavy mfg. export share (%) C. Agg. Welfare Gain (%)

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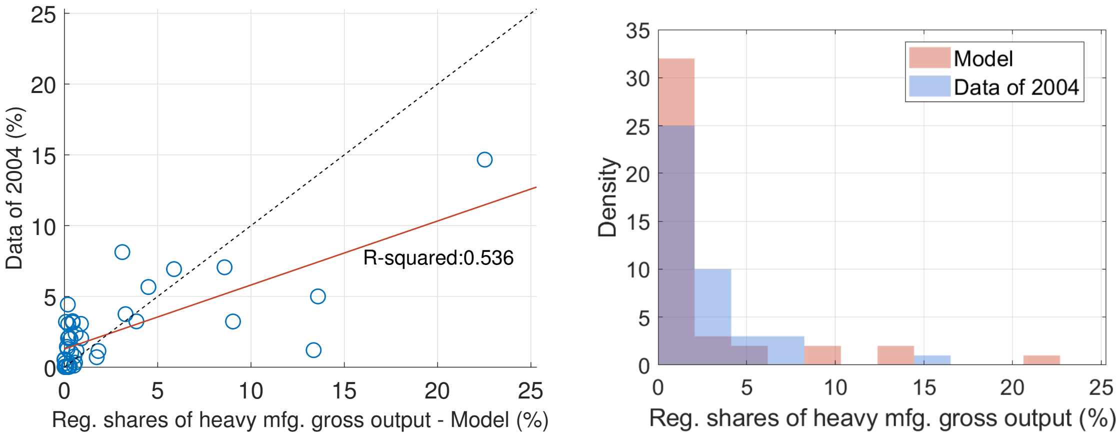
Non-targeted Moments: Spatial Distribution of the Heavy Manufacturing's Gross Output



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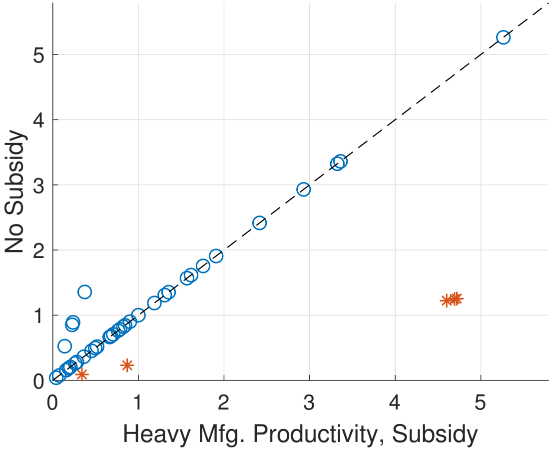
Regional Avg. Productivity Gain

Avg. Productivity $= M_{nj}[\int z_{it}(\phi)^{\sigma-1} dG_{njt}(\phi)]^{1/(\sigma-1)}$



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