Innovation and Trade Policy in a Globalized World

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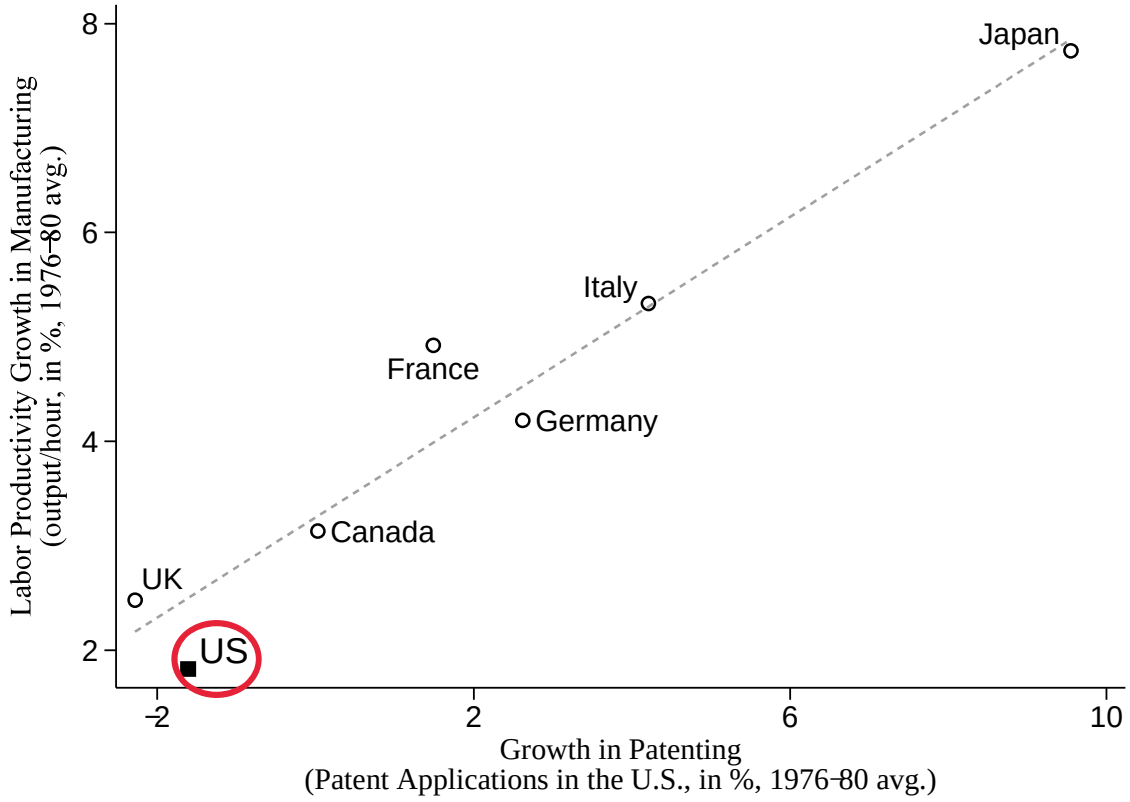
[†]The views expressed here are those of the authors and do not necessarily reflect those of the Board of Governors or the Federal Reserve System.

Motivation - United States in the Late 1970s



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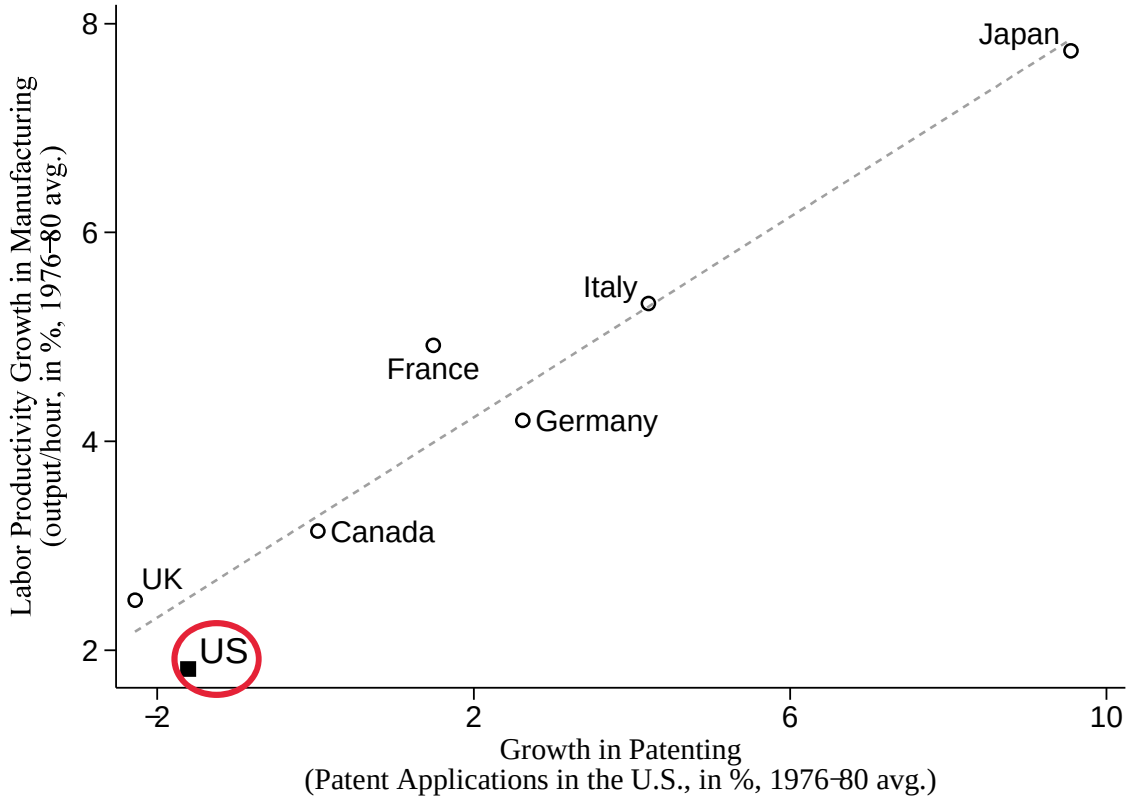


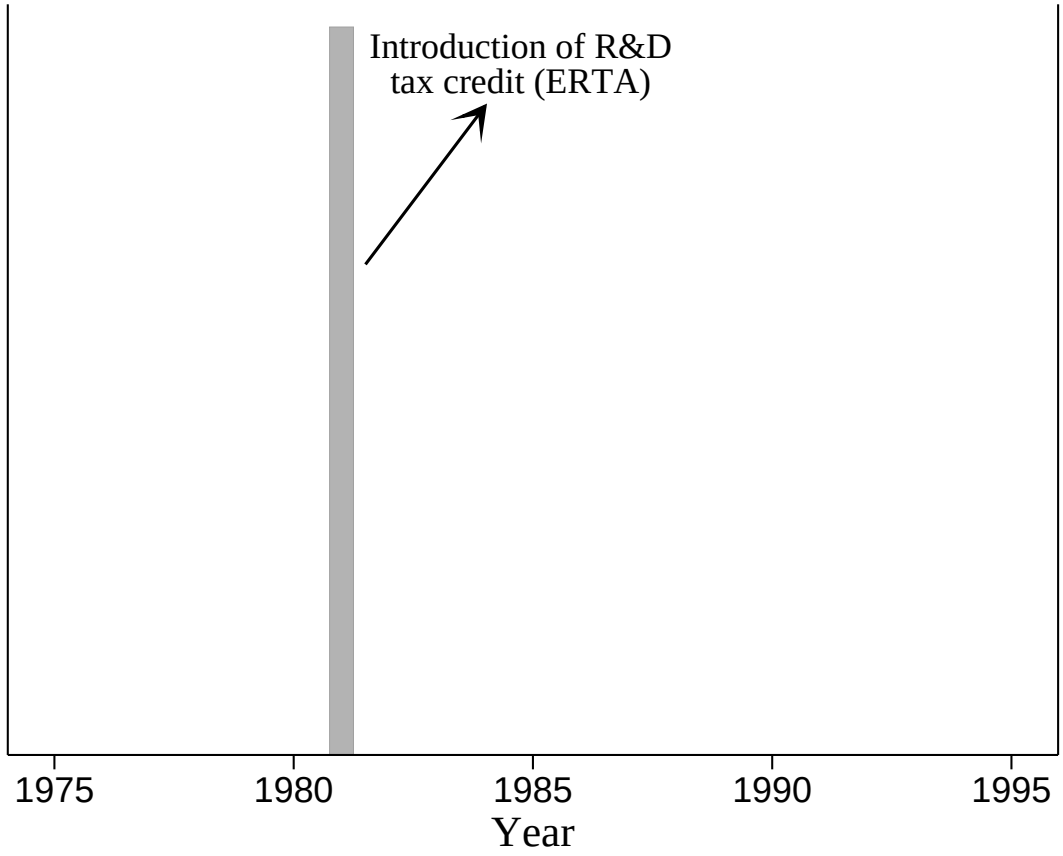
"Foreign competition in the technology intensive industries poses a more serious threat to our country's position in the international marketplace than ever before in our history."

John P. McTague (1985)[a]

[a] Associate Director of the Office of Science and Technology Policy of the Reagan Administration.

quote

Make America Great Again!



Numbers above bars denote number of states with R&D tax credit.
Abbreviations refer to names of states with positive R&D tax credit.
Source: Authors' calculations, Wilson (2009)

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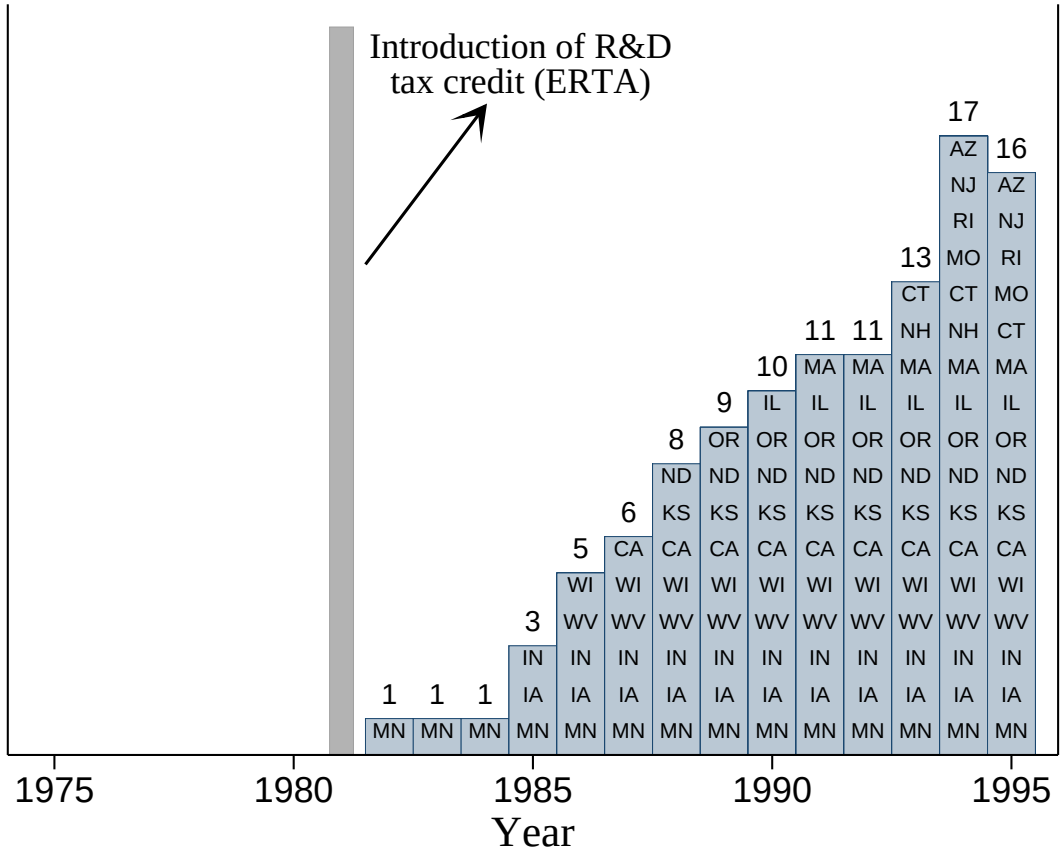

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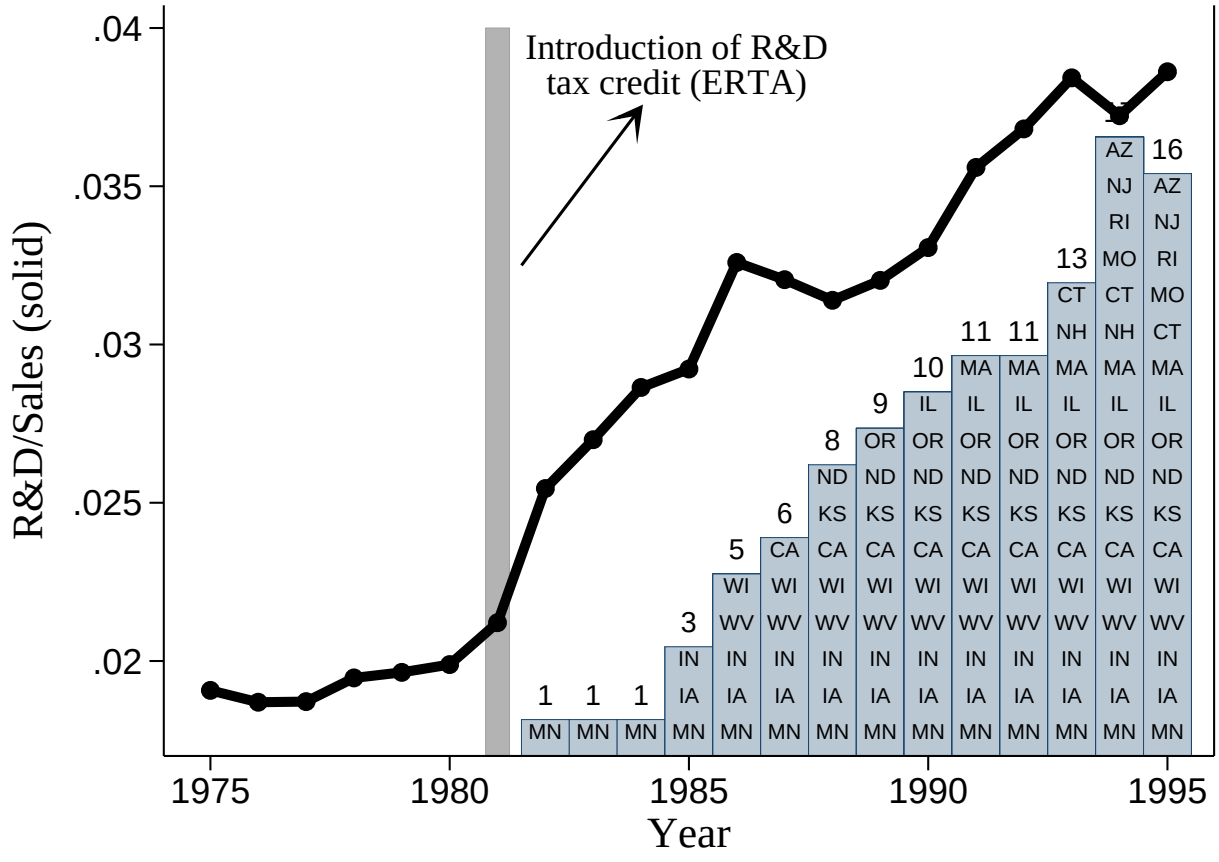

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— R&D Intensity

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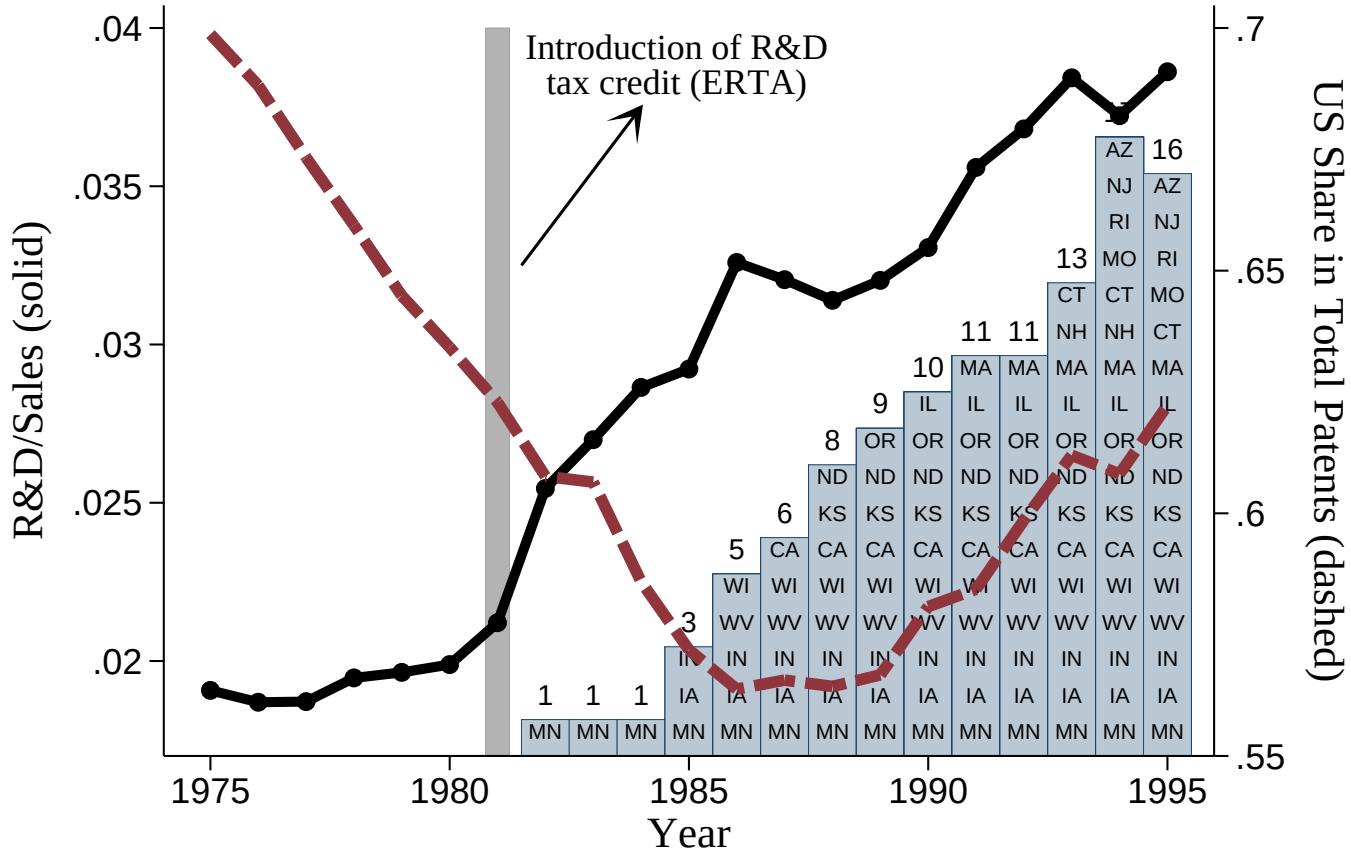

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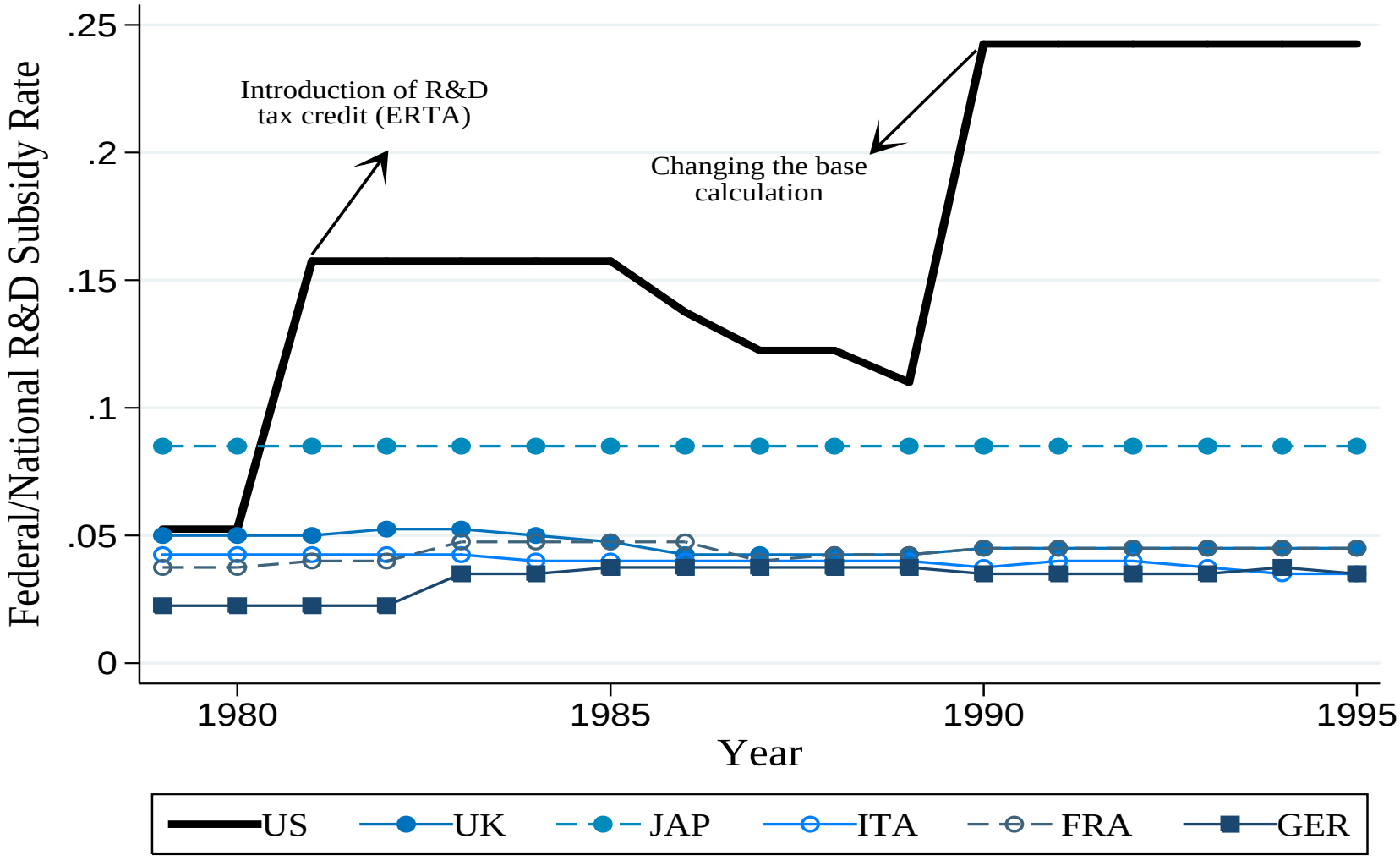
— R&D Intensity - - - Patenting Share of the U.S.

R&D Policies in Other Countries



R&D subsidies were prominent only in the U.S.

sectors

Motivating Questions

1. What are the welfare effects of industrial policies in an open economy faced with foreign technological competition?
    - **Protectionism** vs. **R&D subsidies**
2. How do the implications depend on the policymaker's horizon?
    - **Short run** vs. **Long run**

Motivating Questions

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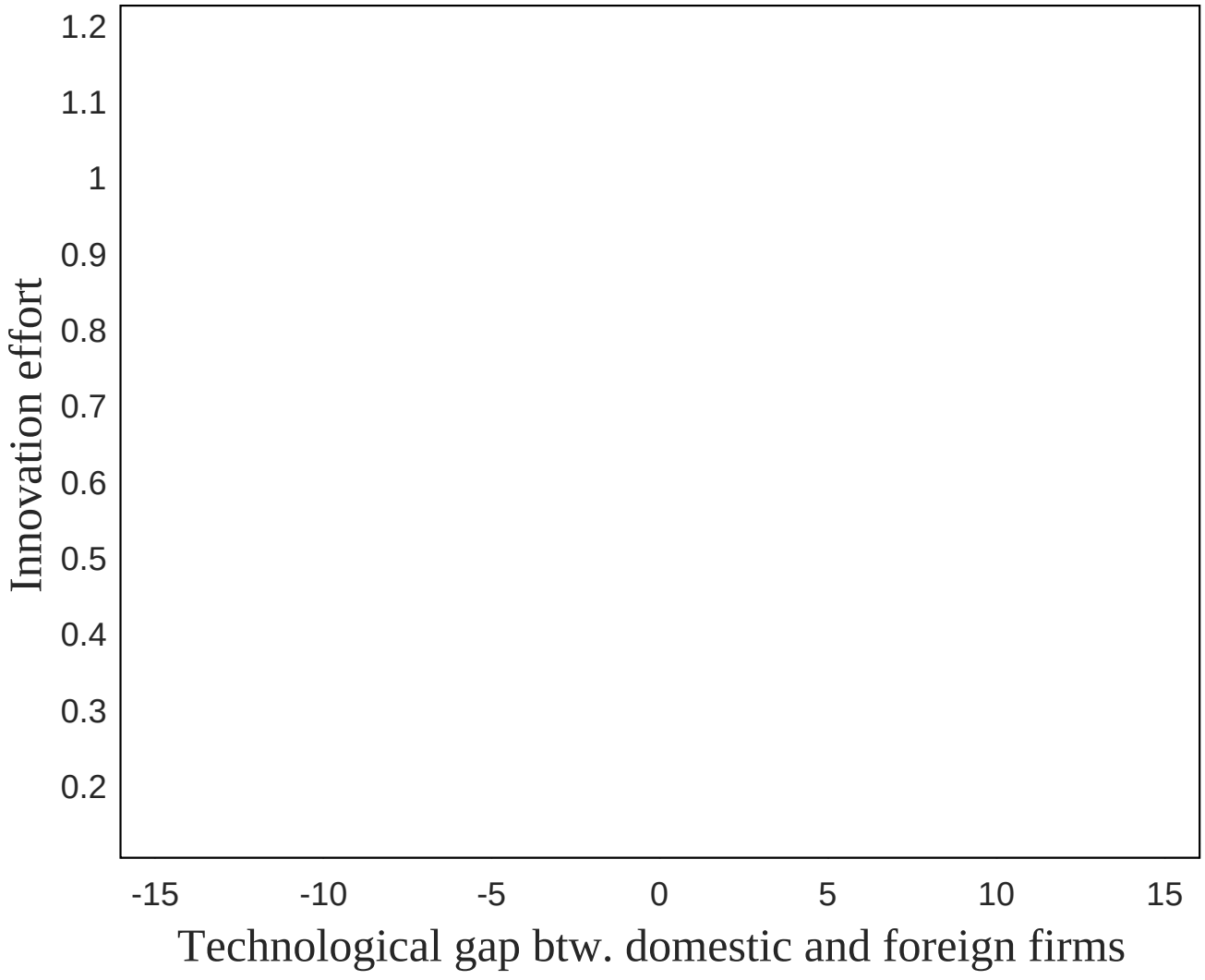
   - **Short run** vs. **Long run**

- A good framework should also incorporate the non-monotonic empirical link between *import competition* and *innovation* as in **Bloom et al. (2016)** and **Autor et al. (2016)**, among many others.

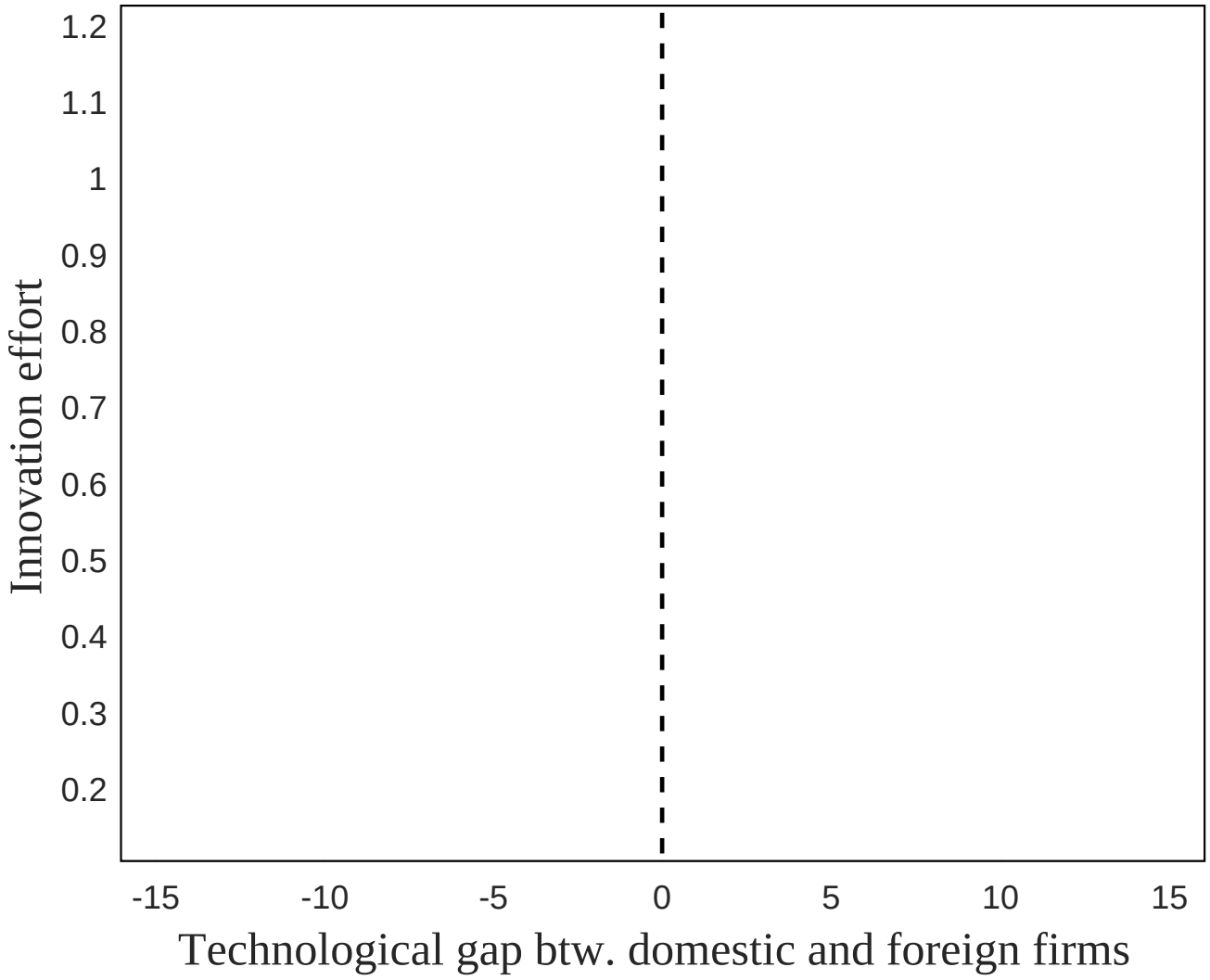
To Answer These Questions...

1. **New Micro Evidence**
2. **Model**
   - Two large open economies subject to trade frictions
   - Dynamic general equilibrium with endogenous incumbent innovation
   - Step-by-step innovation with strategic interaction between firms
   - Endogenous entry-exit of firms
   - Transitional dynamics: important for policy horizon
3. **Quantitative Policy Analysis**
   - Evaluate policies in different policy horizons
     - One-sided trade policy
     - Incumbent R&D subsidy
     - Two-sided trade policy (retaliation)
     - Optimal policies

Main Mechanism in the Model



Main Mechanism in the Model



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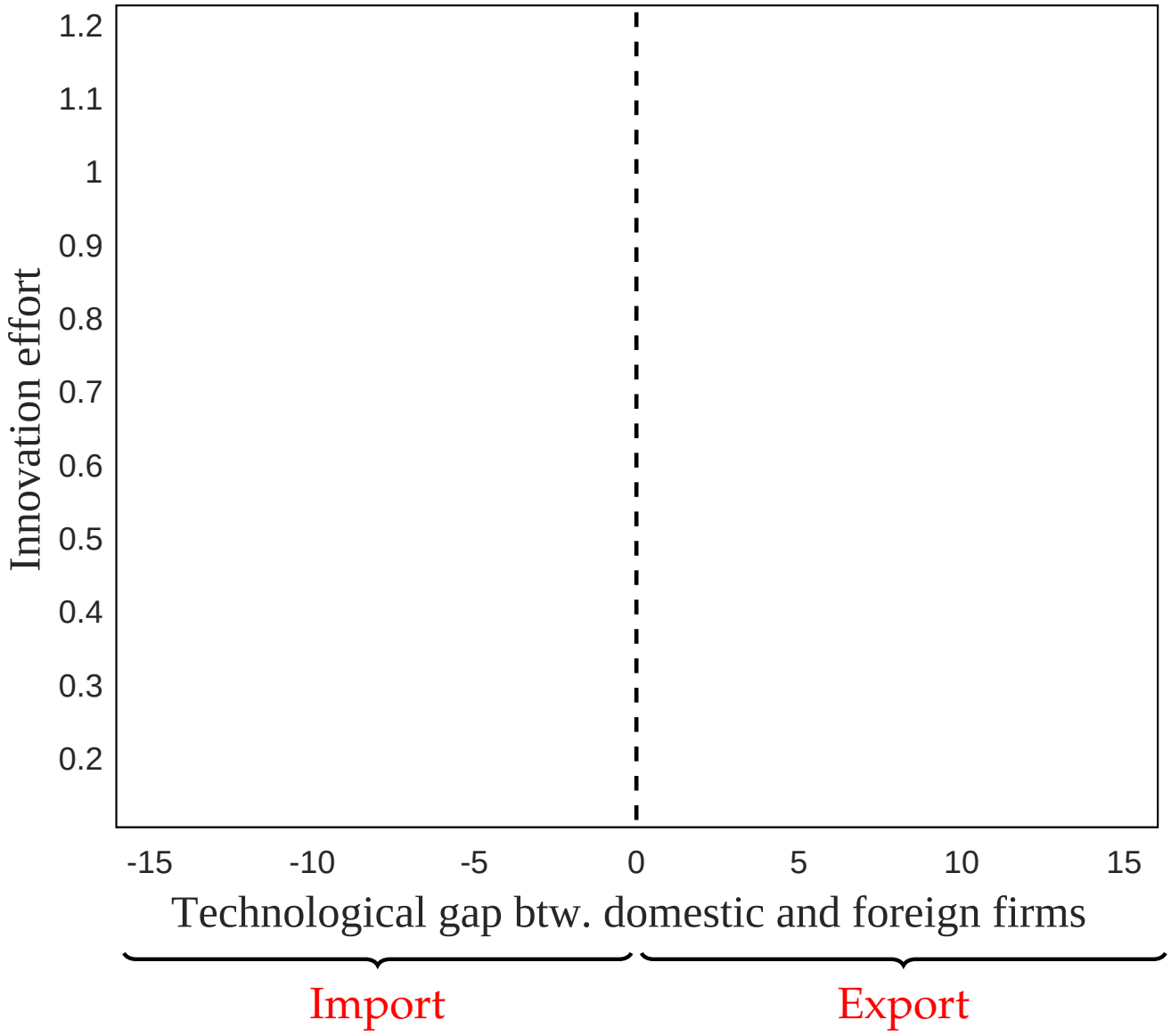

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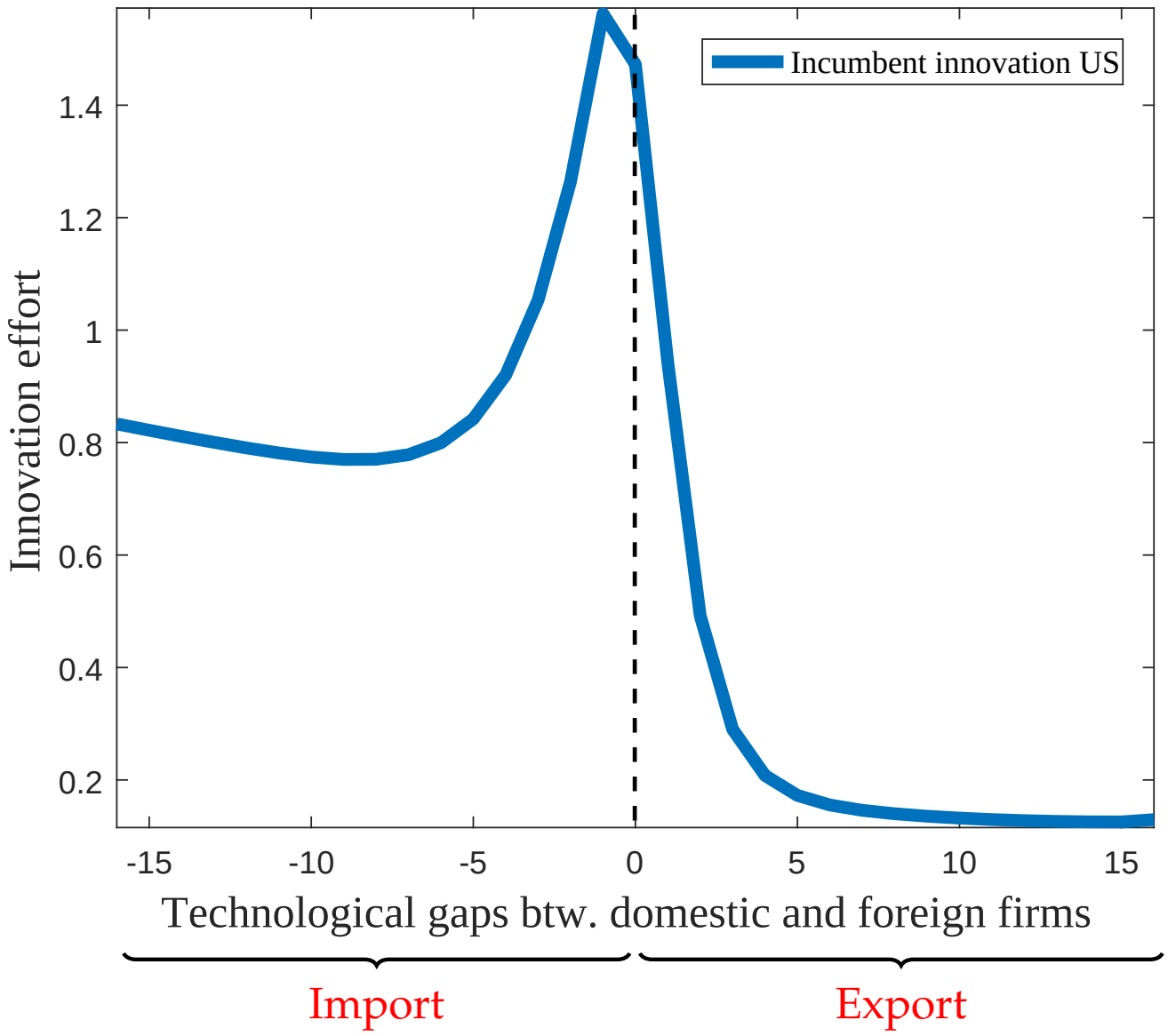
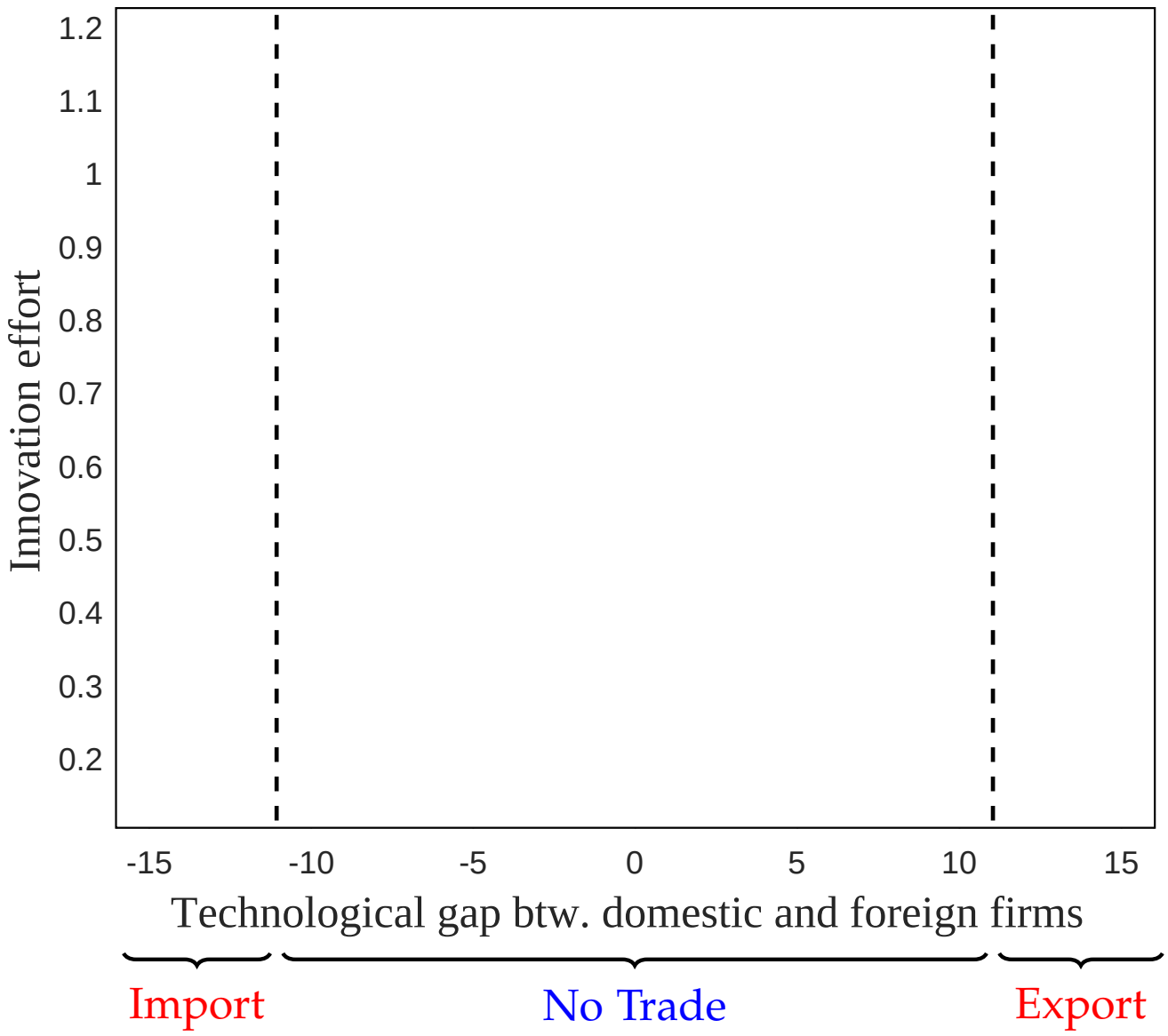


Main Mechanism in the Model



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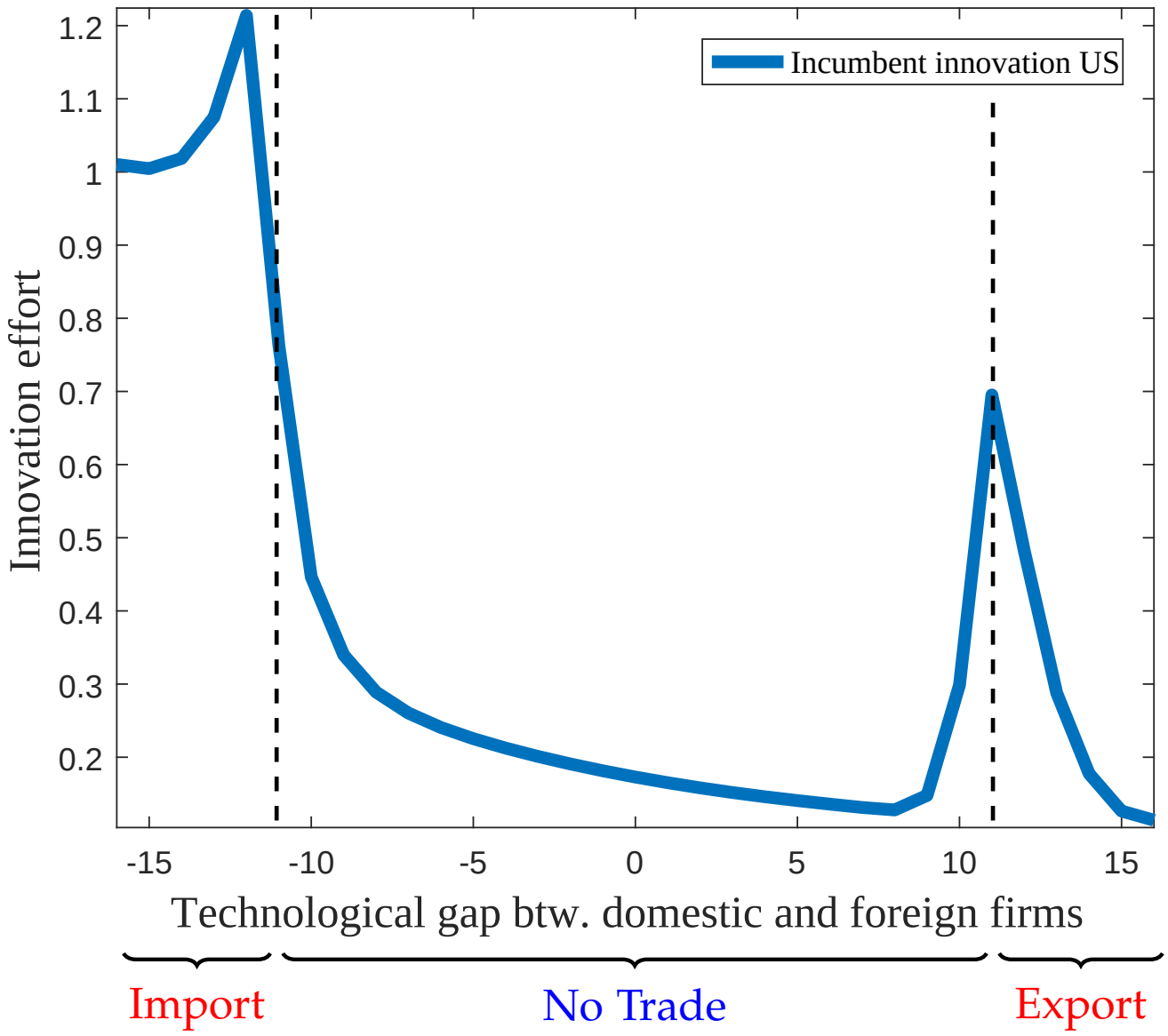

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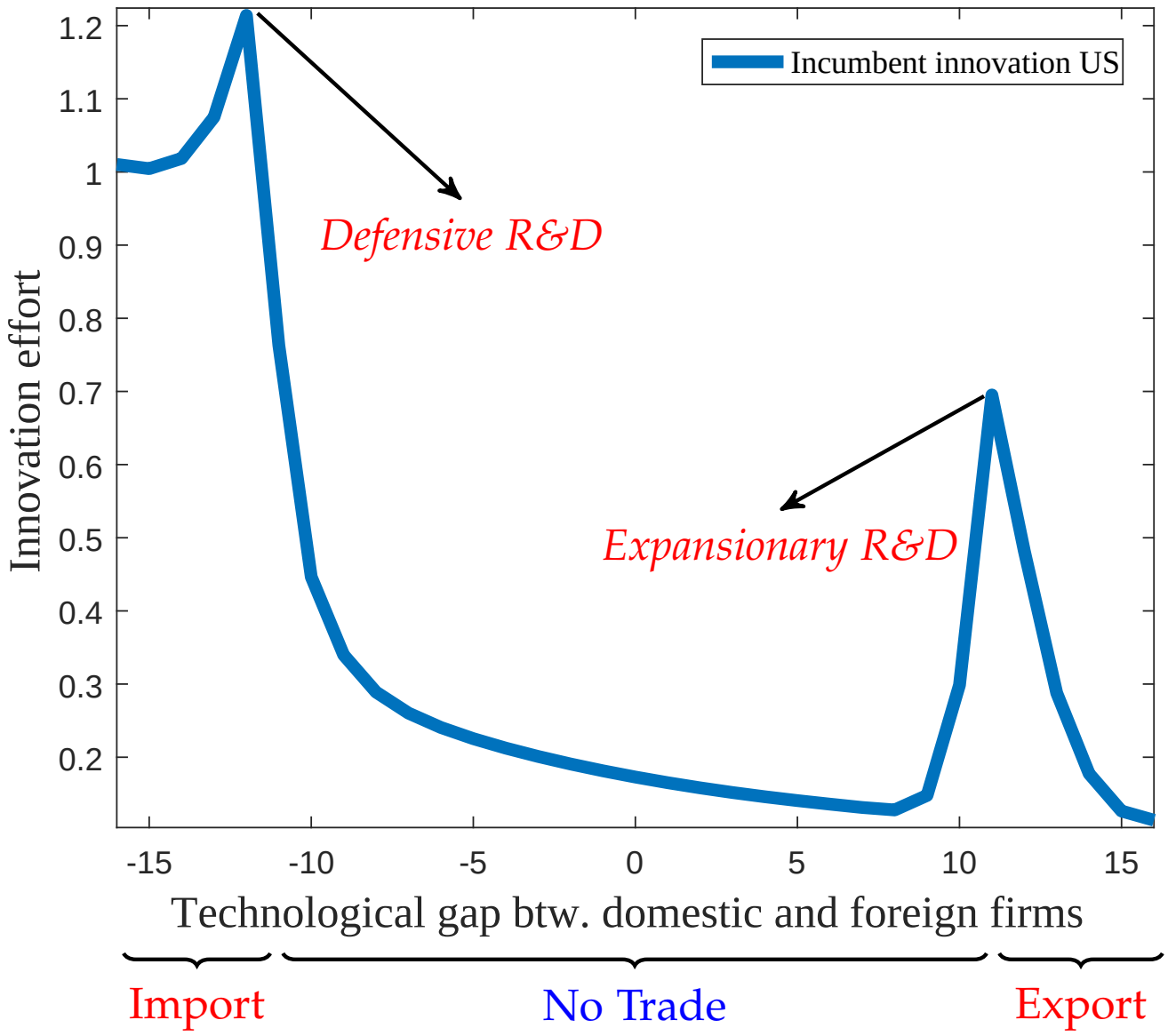
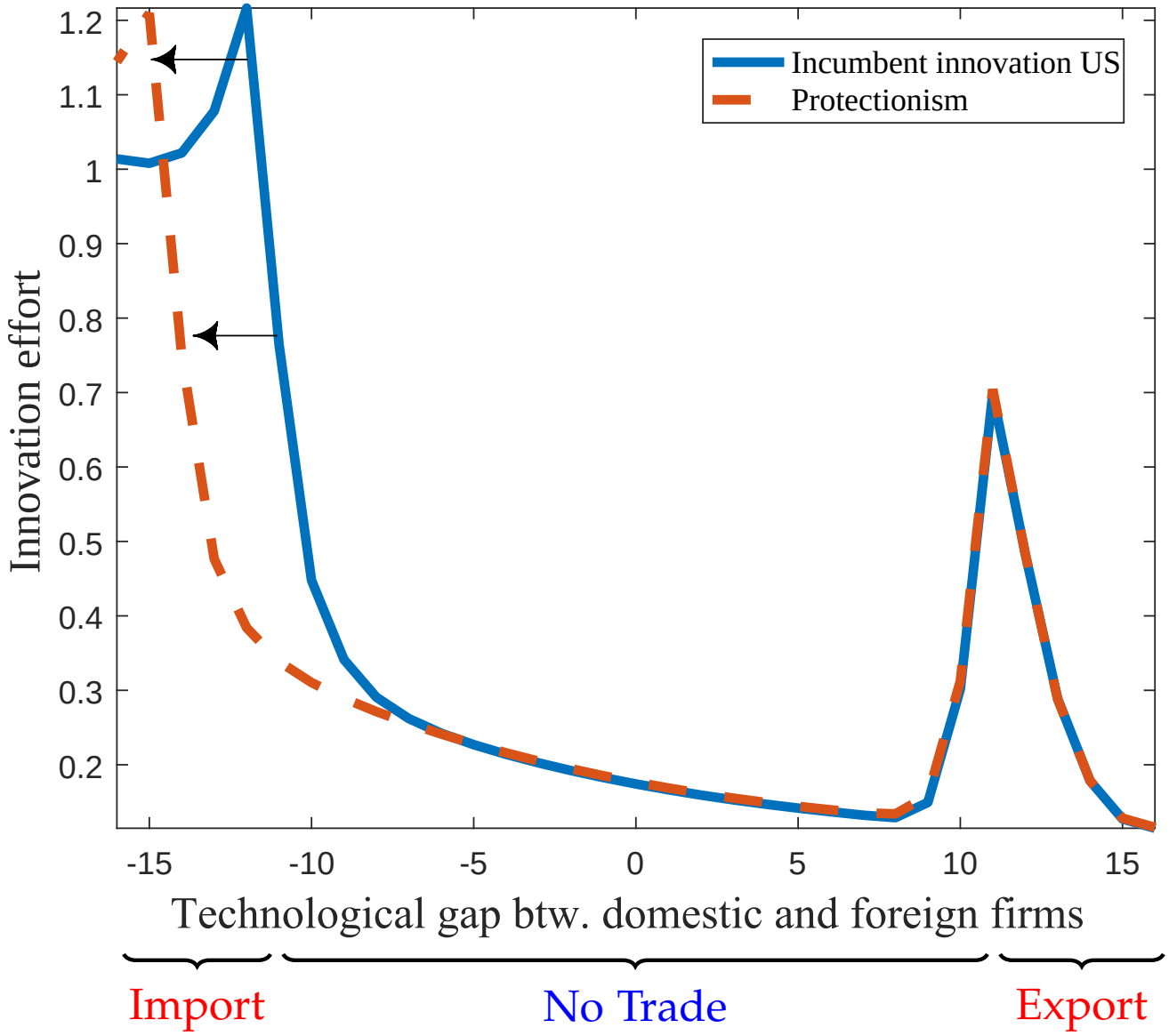


Main Mechanism in the Model

PROTECTIONISM



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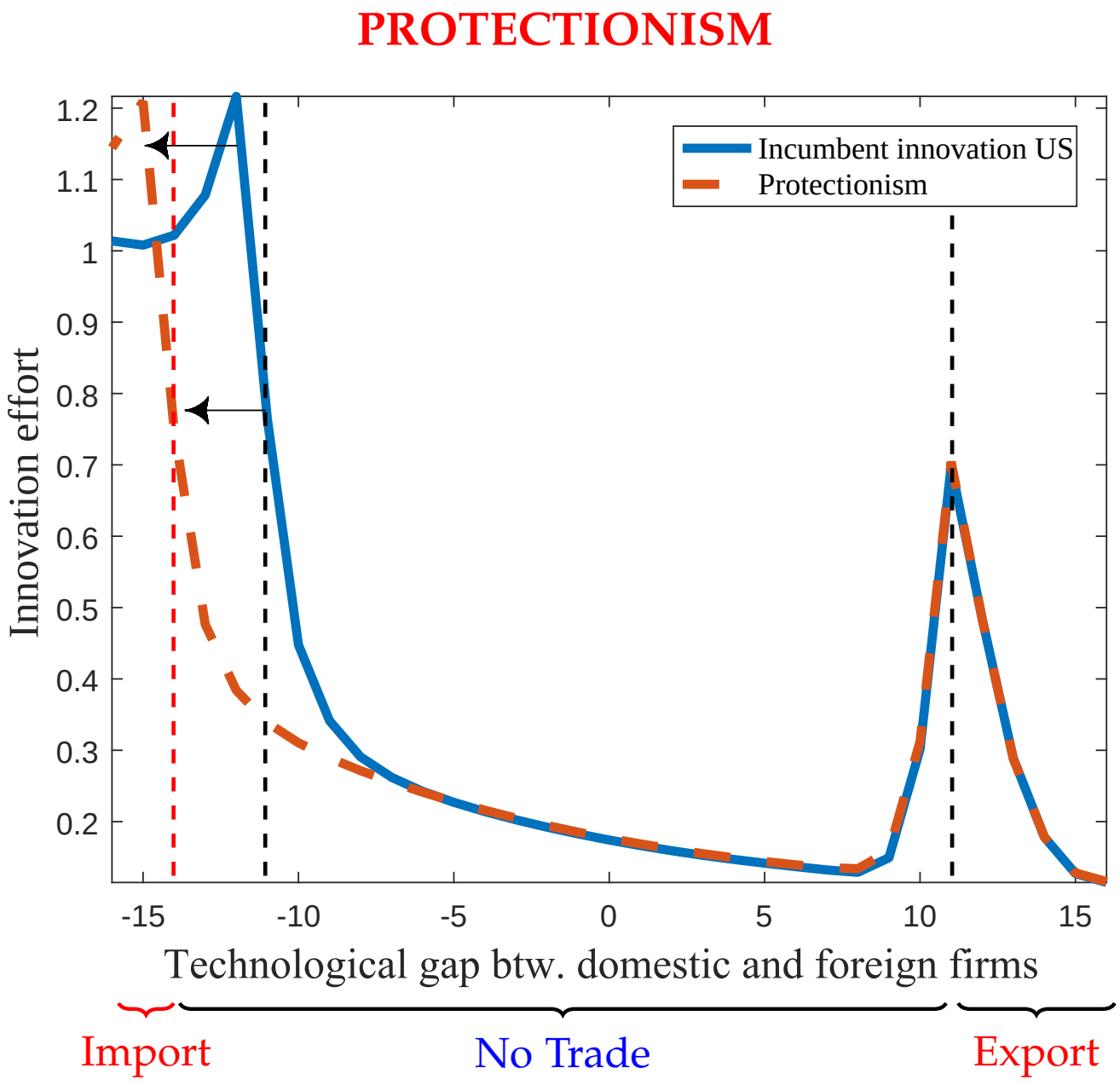
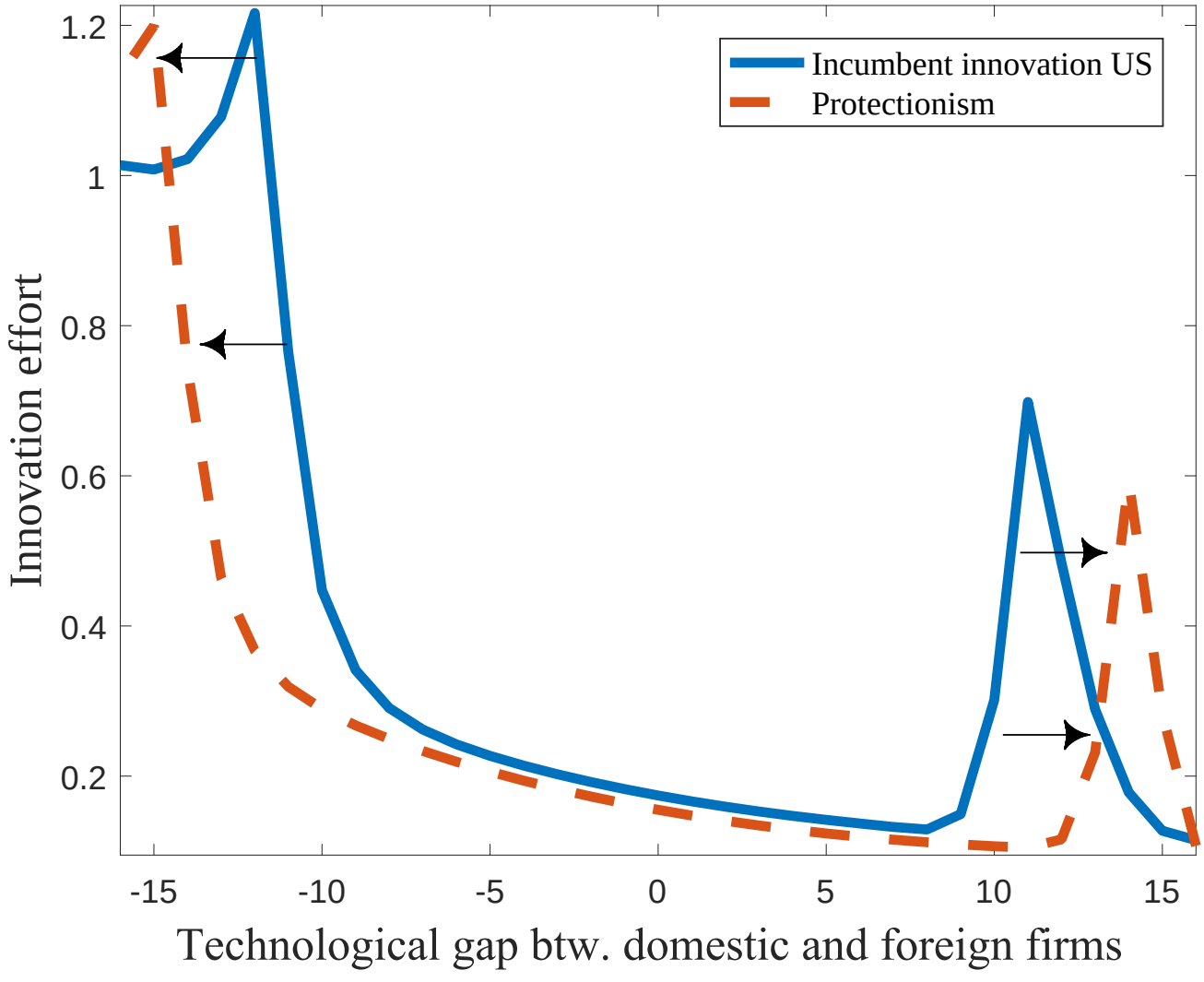


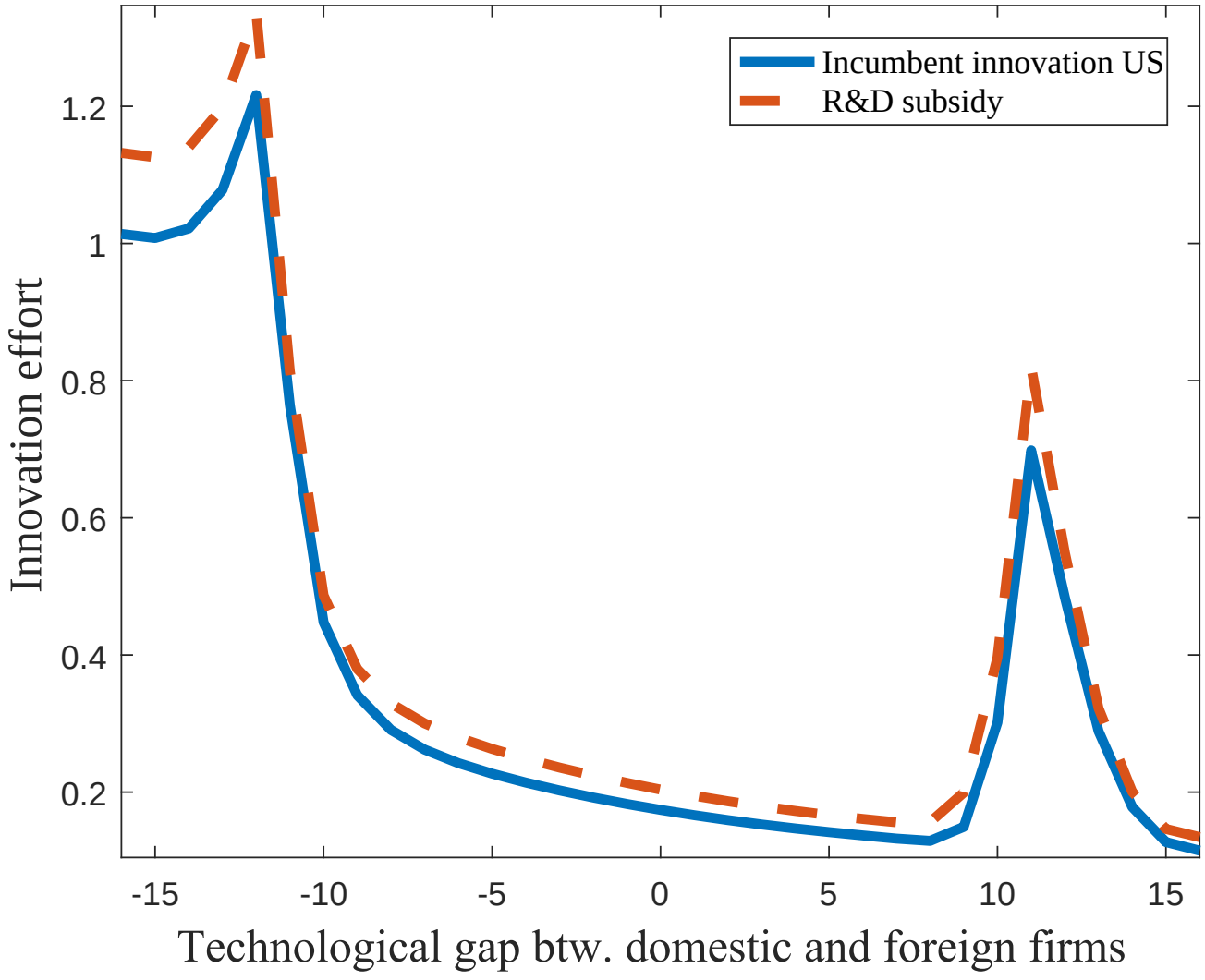
Main Mechanism in the Model

RETALIATION



Main Mechanism in the Model

R&D SUBSIDY



Preview of the Results

1. **Static effects:**
   - Protectionism "could potentially" benefit the domestic economy.
     $\rightarrow$ profit shifting

2. **Dynamic effects:**
   - Openness leads more innovation through competition:

     - Domestic market: defensive innovation
     - Foreign market: expansionary innovation

   - Openness $\rightarrow$ Technology transfer, spillover

3. **Protectionism:** Welfare gains only if it is
   - one sided, AND, in the short run (up to 20 yrs.)

4. **R&D subsidies:** Dominant policy for long-sighted policy makers

5. **Policy complementarity:** Globalization $\rightarrow$ less need for policy intervention (markets would take care of themselves).

6. **Optimal policy mix:** The interplay with retaliatory response

MODEL

Part 1. Static Environment

Preferences and Final Good

- Final good in country c produced with technology

$$Y_c = \frac{L_c^{\beta}}{1-\beta} \int_0^1 q_{c'j}^{\beta} k_{c'j}^{1-\beta} dj, \text{ where } c' \in A, B \tag{1}$$

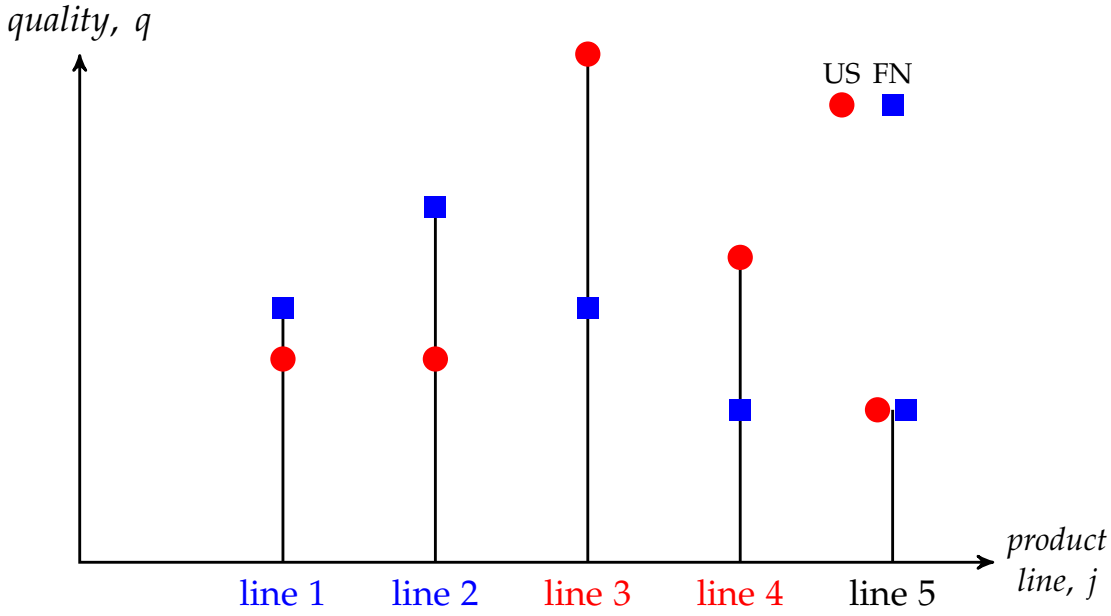
  - L_c: Fixed factor, immobile, normalized to 1.
  - q_{cj}: quality of variety j in country c
  - k_{cj}: amount of variety j used.

- Implies that the highest quality good (adjusted for trade cost) is purchased.

- Final good producer's maximization gives:

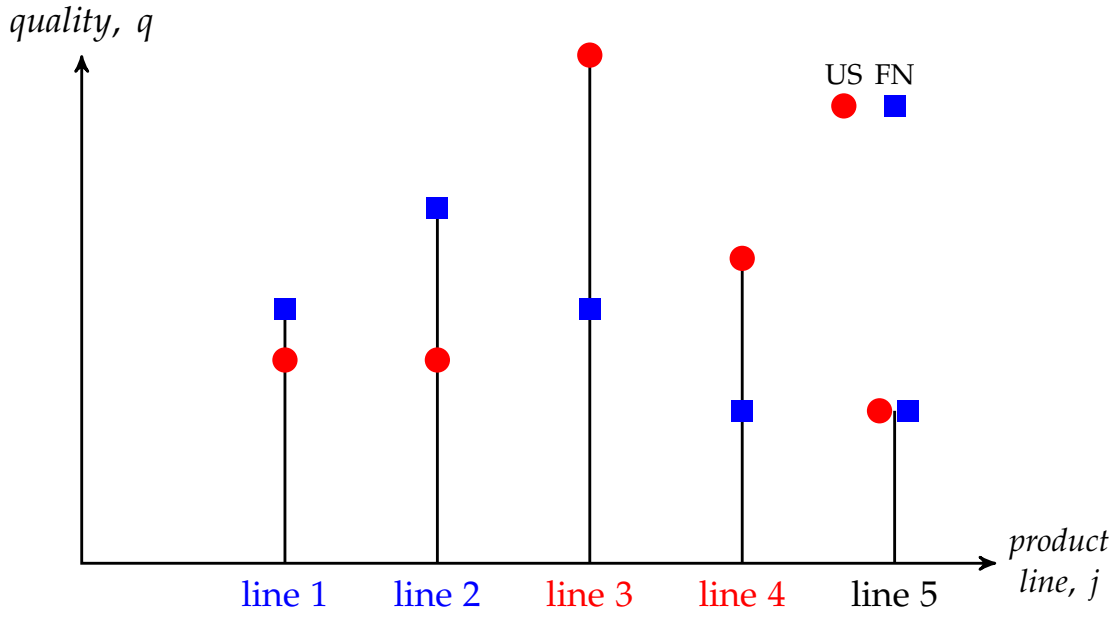
$$p_j = q_j^{\beta} k_j^{-\beta}.$$

Intermediate Goods - production



Model Economy

Intermediate Goods - production

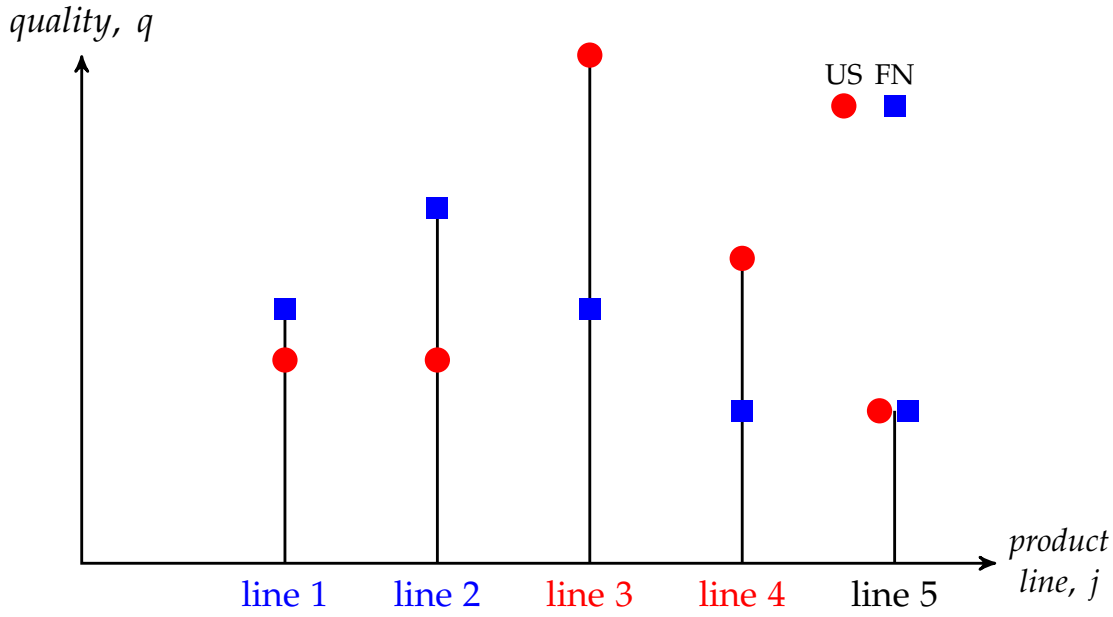


Model Economy

In each j, one firm per country competing for leadership à la Bertrand.

$$\text{Tech. Leadership in } j = \begin{cases} US \text{ is leader,} & \text{if} \quad q_{US,j} > q_{FN,j} \\ FN \text{ is leader,} & \text{if} \quad q_{US,j} < q_{FN,j} \\ \text{Neck\&Neck,} & \text{if} \quad q_{US,j} = q_{FN,j} \end{cases}$$

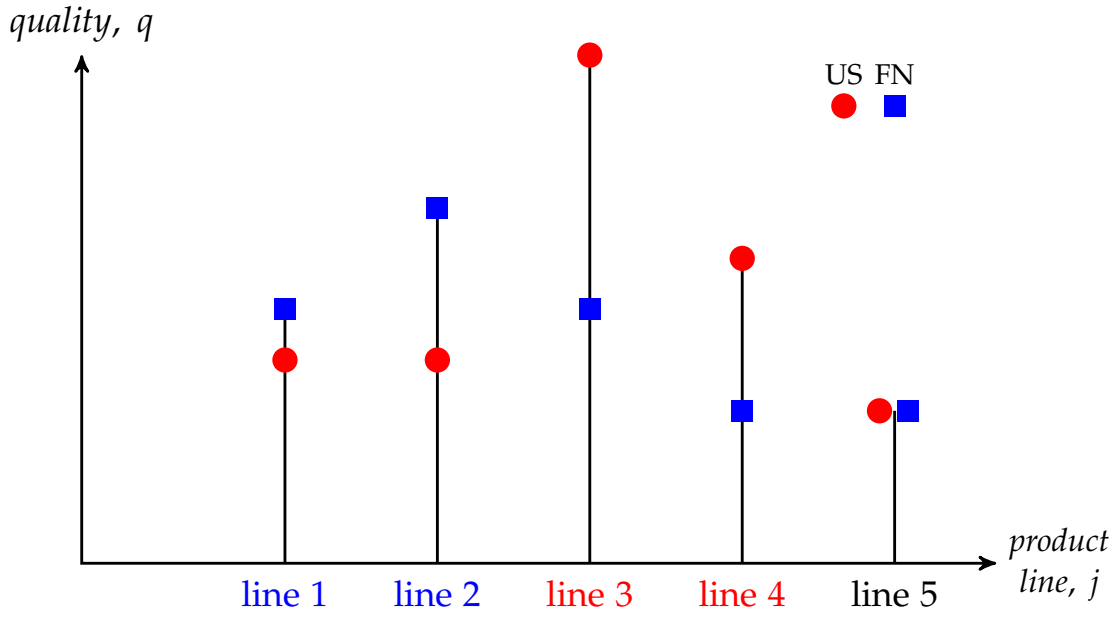
Intermediate Goods - production



Model Economy

Qualities evolve through **innovation** and **spillovers** (to be explained later).

Intermediate Goods - production



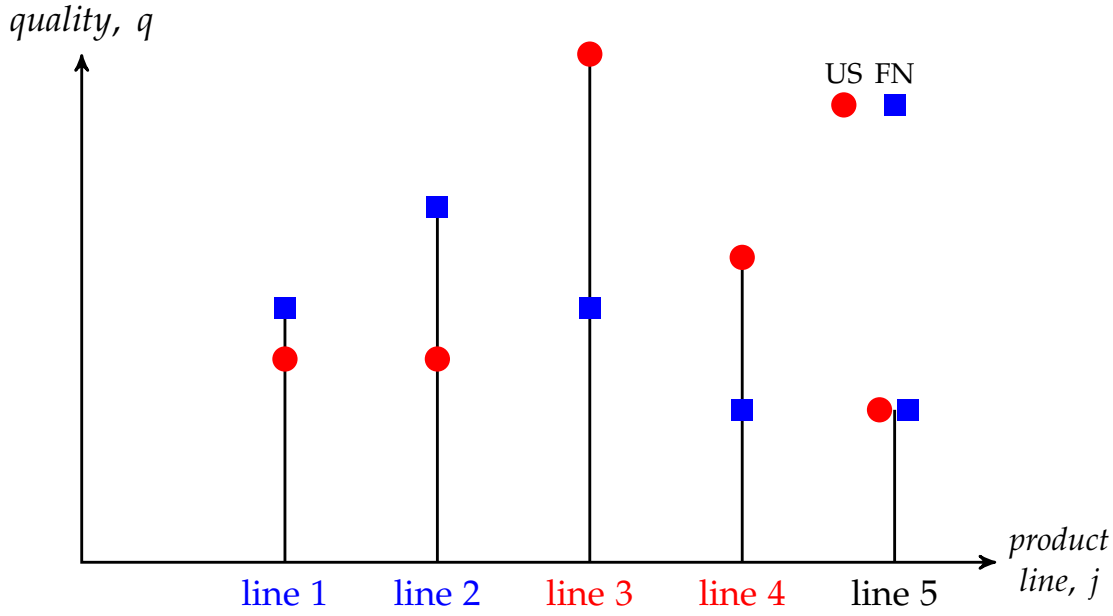
Model Economy

Intermediate goods are produced at the marginal cost of η in terms of final good.

$$\Pi\left(q_j\right) = \max_{k_j \geq 0} \left\{ q_j^{\beta} k_j^{1-\beta} - \eta k_j \right\}.$$

Robustness I: *Labor in the intermediate good production.*

Intermediate Goods - production



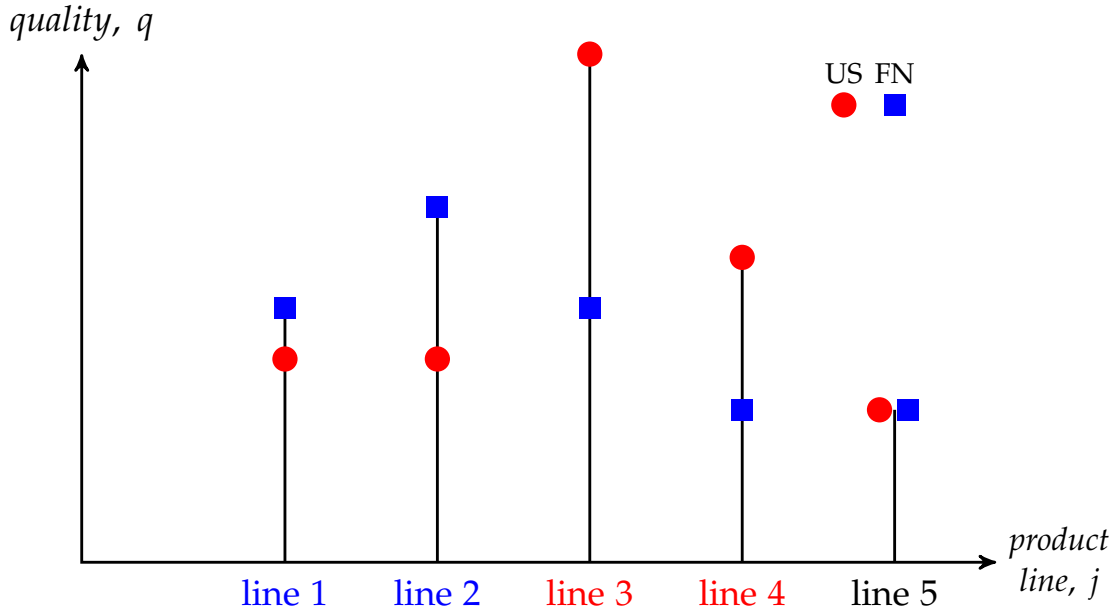
Model Economy

Selling abroad has export (iceberg) cost κ and subject to tariff τ^{FN}.

$$\hat{\Pi}\left(q_j\right) = \max_{k_j \geq 0} \left\{ q_j^{\beta} k_j^{1-\beta} - (1 + \kappa + \tau^{FN}) \eta k_j \right\}.$$

Robustness II: *Tariff revenue transferred back to the HH.*

Intermediate Goods - production



Model Economy

Resulting equilibrium profits:

Profit in the domestic market: $\Pi(q_j) = \left(\frac{1-\beta}{\eta}\right)^{\frac{1-\beta}{\beta}} \beta q_j$

Profit in the foreign market: $\hat{\Pi}(q_j) = \left(\frac{1-\beta}{(1+\kappa+\tau^{FN})\eta}\right)^{\frac{1-\beta}{\beta}} \beta q_j$

Export vs. Import Decisions

Actual market ownership depends on *technological leadership* and *trade costs*:

- US exports in sector j iff

$$\frac{q_{USj}}{q_{FNj}} > (1+\kappa)^{\frac{(1+\beta)}{\beta}}$$

- US imports in sector j iff

$$\frac{q_{FNj}}{q_{USj}} > (1+\kappa)^{\frac{(1+\beta)}{\beta}}$$

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$$\frac{q_{FNj}}{q_{USj}} > (1+\kappa)^{\frac{(1+\beta)}{\beta}}$$

MODEL

Part 2. Dynamic Environment

Intermediate Goods - innovation

- Qualities evolve through **innovation** and **spillovers**.
- Successful **innovation** generates quality jumps btw. t and $t + \Delta t$:

$$q_{cj}(t + \Delta t) = \lambda^n q_{cj}(t)$$

where $\lambda > 1$, $c \in \{US, FN\}$, and $n \in \mathbb{N}^+$ is a random variable.

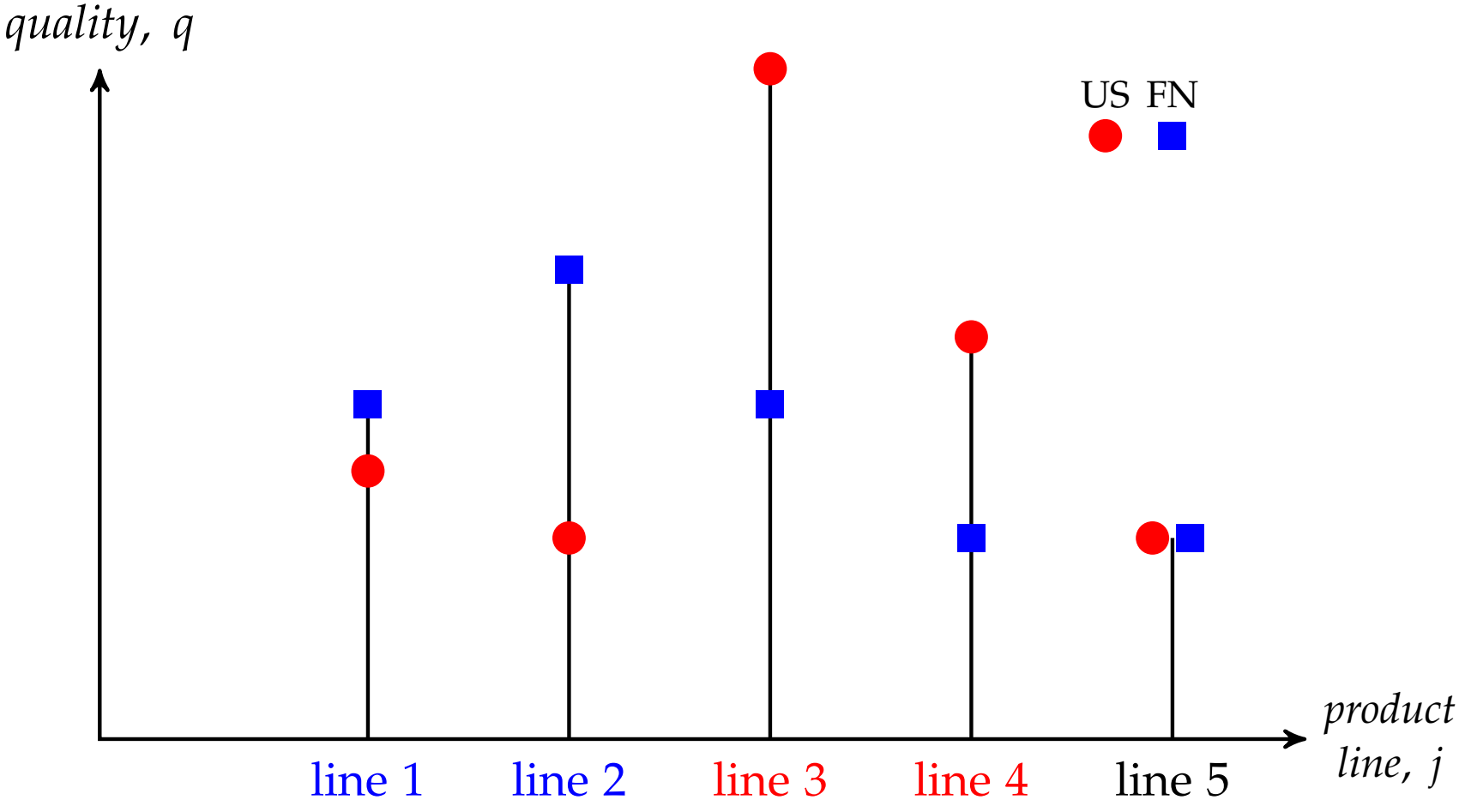
- Hence **technology gap** between US and FN in j:

$$\frac{q_{USj}}{q_{FNj}} = \lambda^{N_{USj} - N_{FNj}} \equiv \lambda^{m_j}$$

- **Assumption.** Max gap is $\bar{m}$:

$$m_j \in \{-\bar{m}, ..., -1, 0, 1, ..., \bar{m}\}$$

Illustration of the Innovation Dynamics



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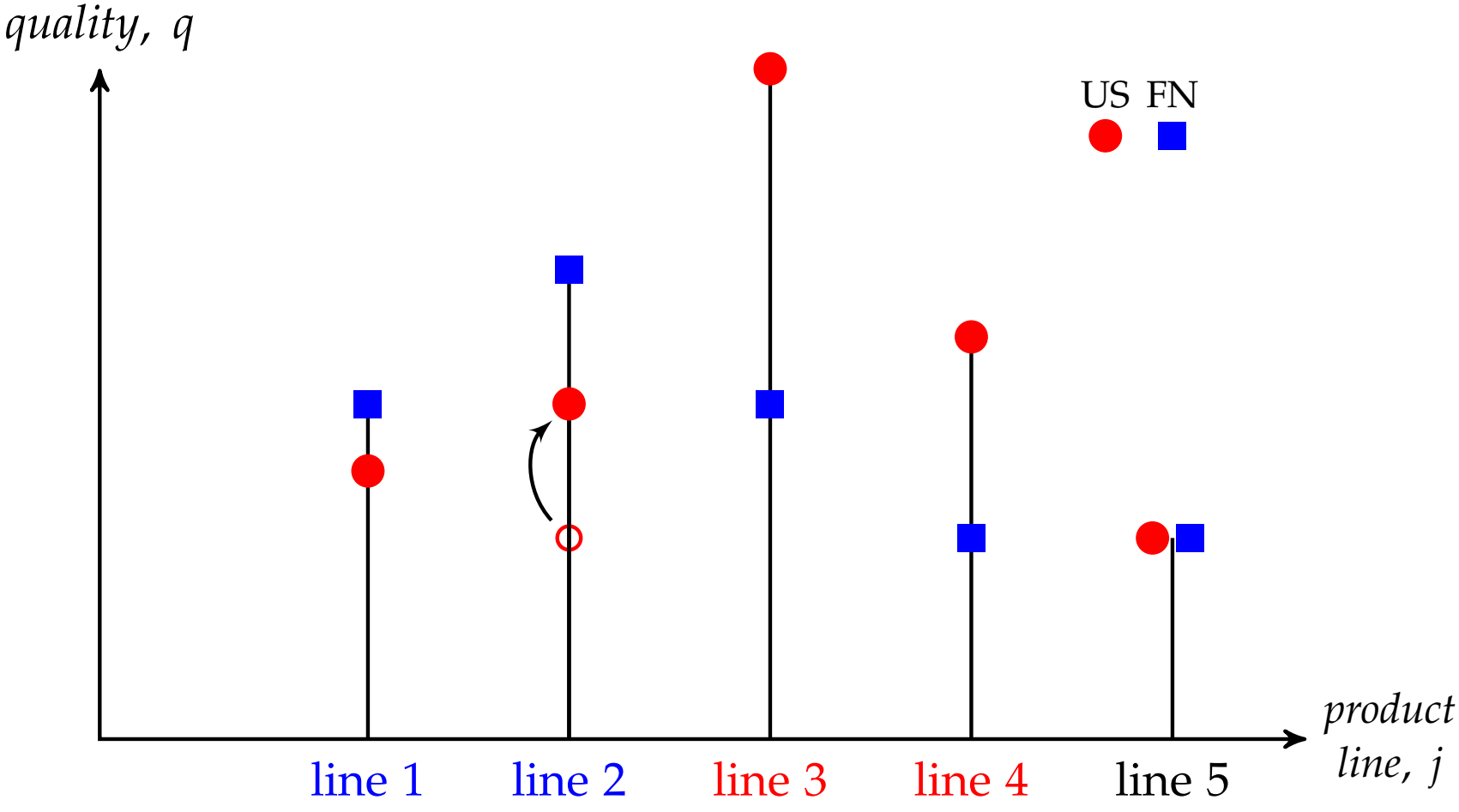
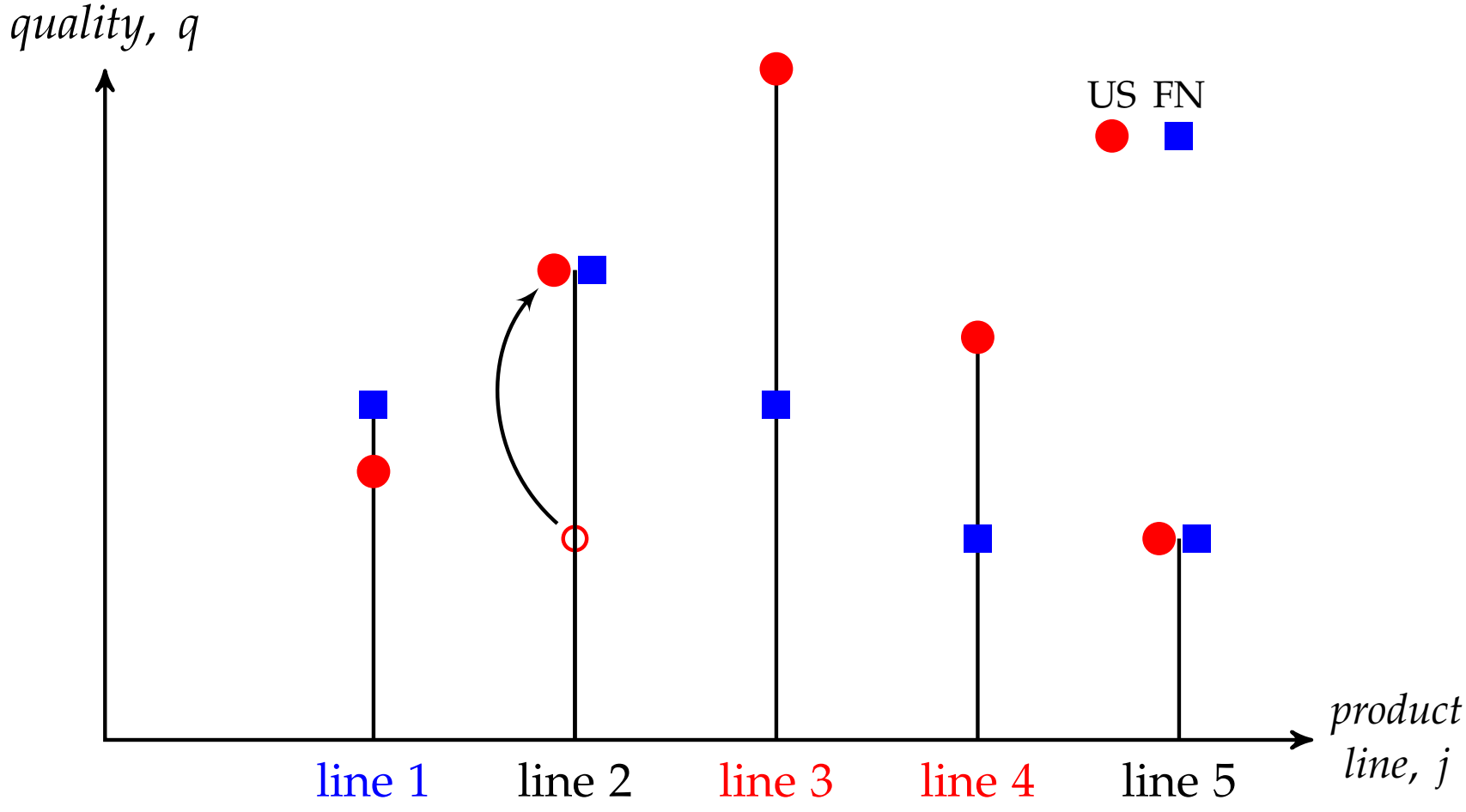


Suppose the follower in line 2 innovates.

- Scenario 1: It closes the gap, but remains follower.

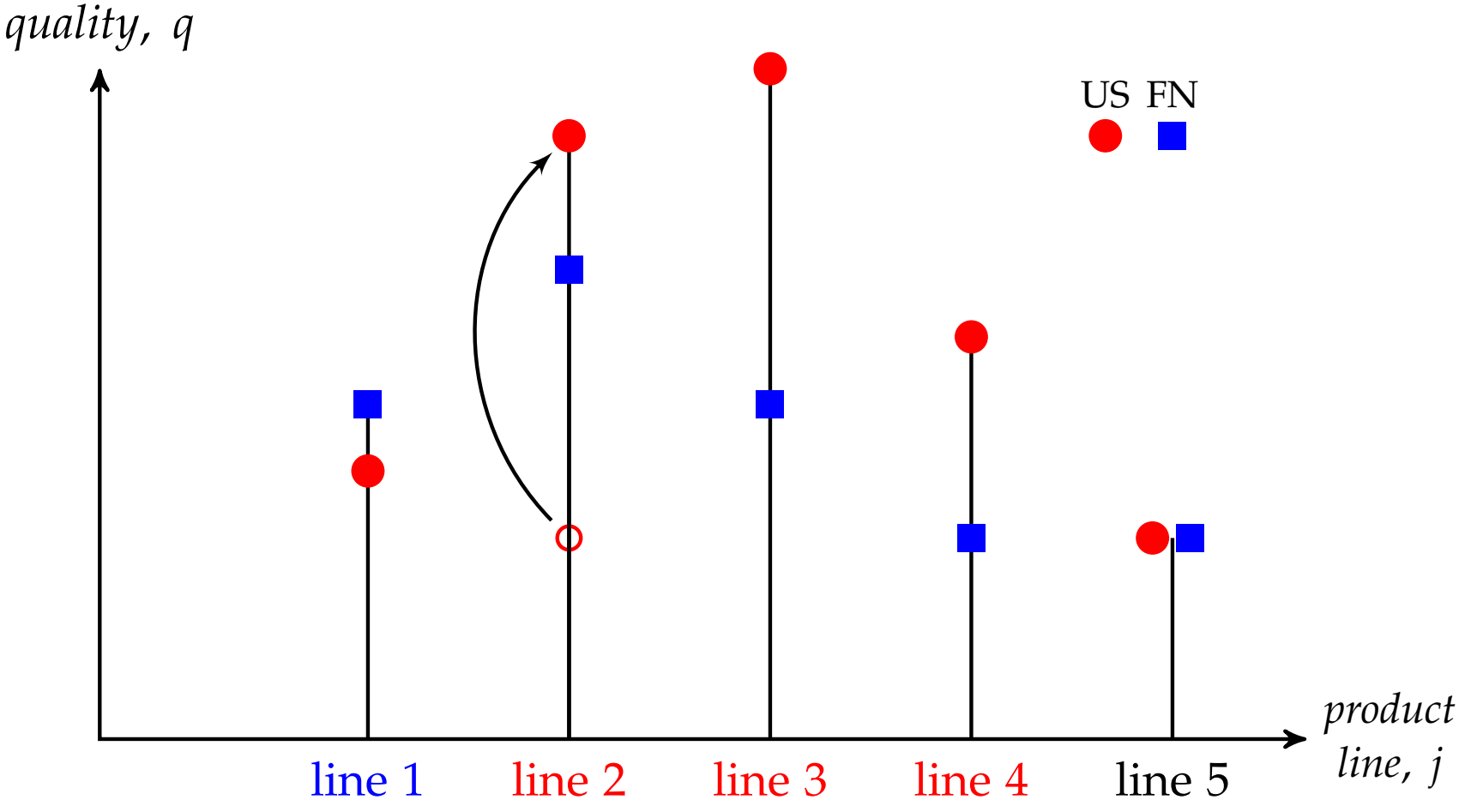
Illustration of the Innovation Dynamics



Suppose the follower in line 2 innovates.

- Scenario 2: It catches up.

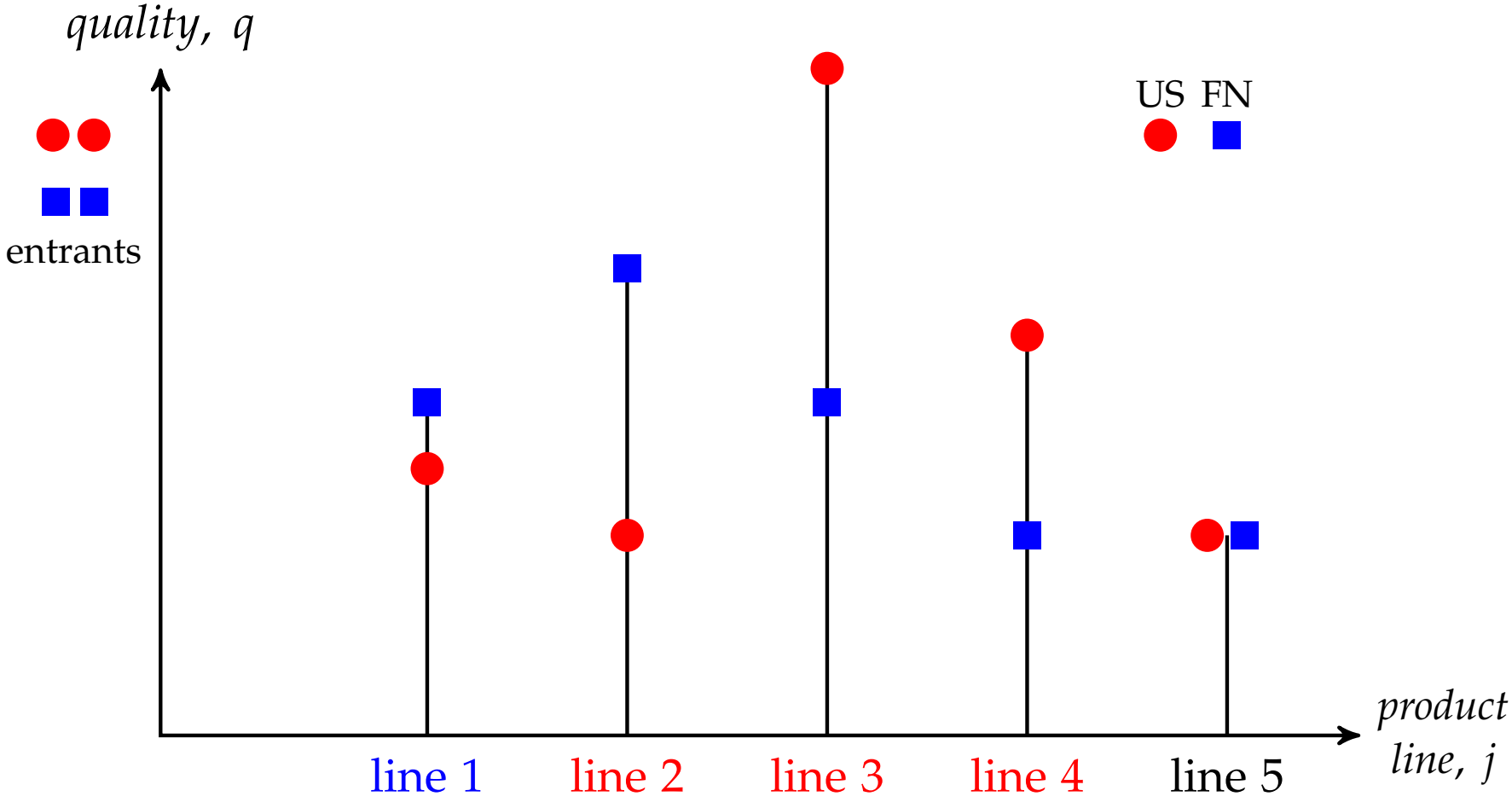
Illustration of the Innovation Dynamics



Suppose the follower in line 2 innovates.

- Scenario 3: It leapfrogs.

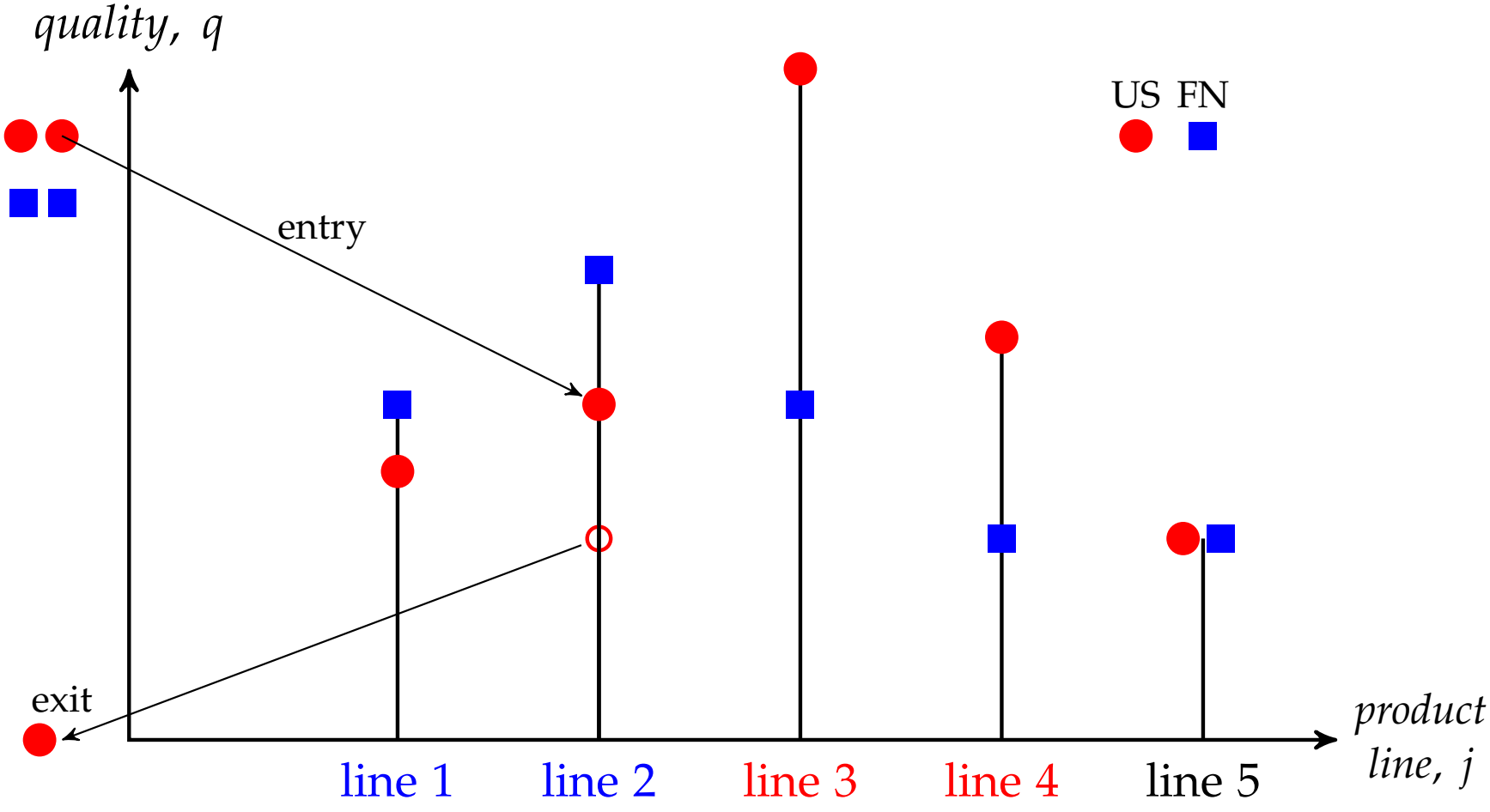
Illustration of the Innovation Dynamics



Free entry leads to similar dynamics ...

- ... but forces the domestic incumbent to exit.

Illustration of the Innovation Dynamics



Free entry leads to similar dynamics ...

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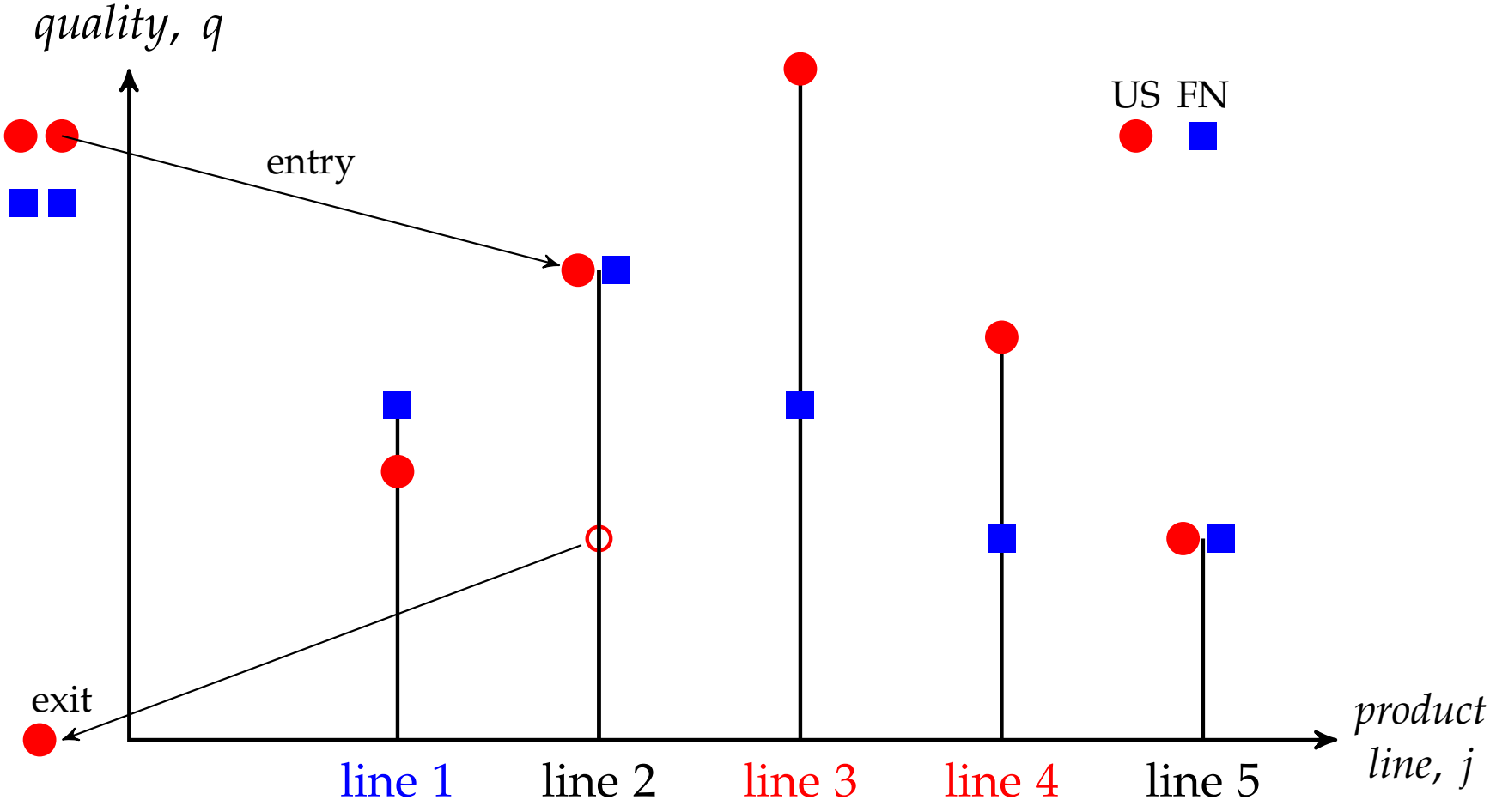

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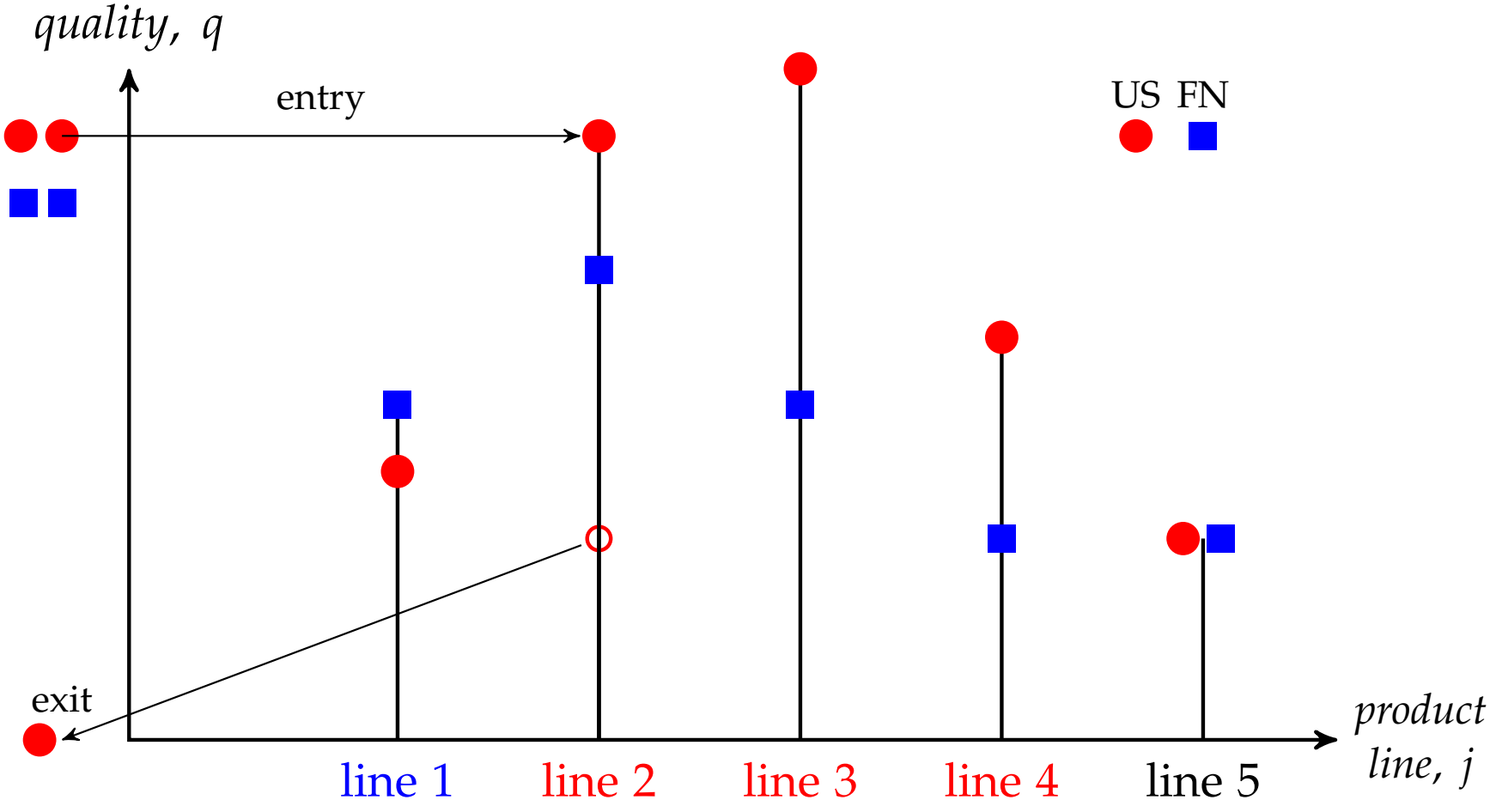

Free entry leads to similar dynamics ...

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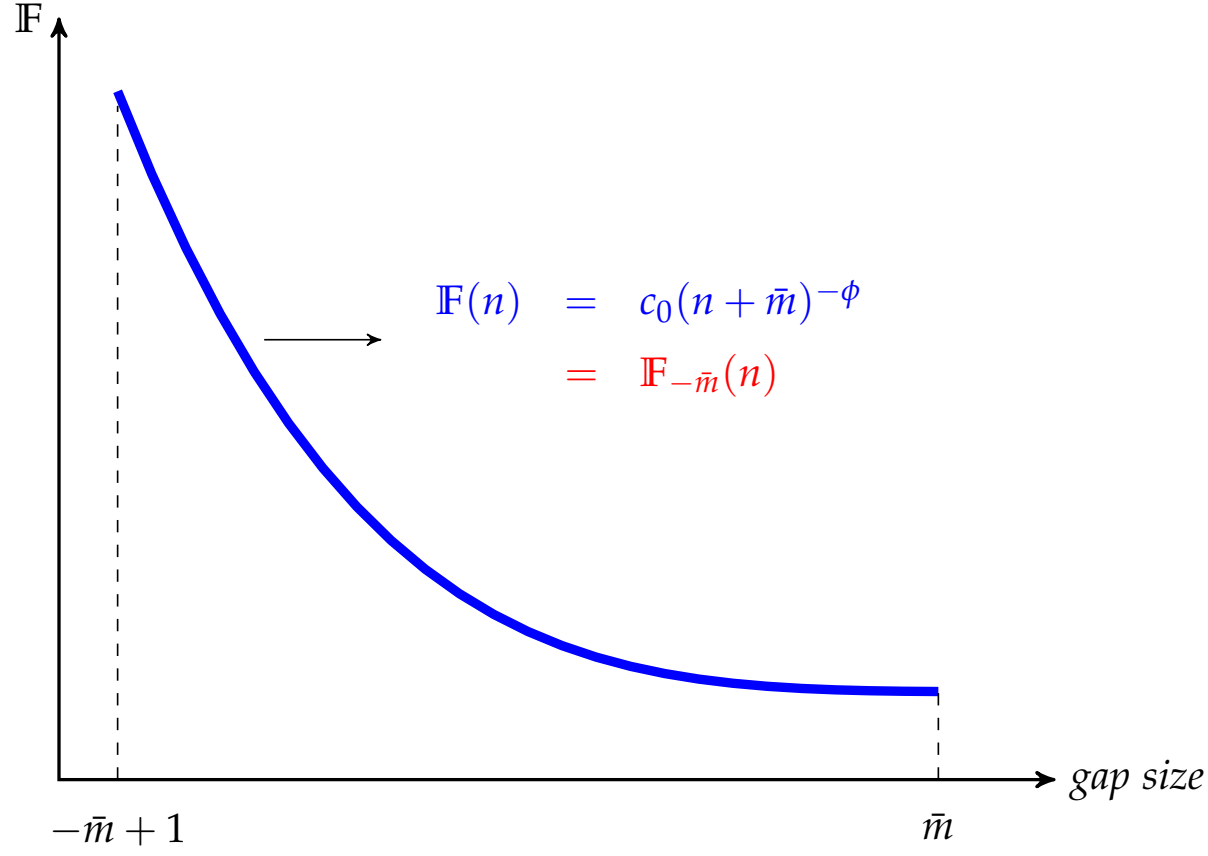
Step Jump Distribution, $\mathbb{F}(n)$



Recall: $q_{cj}(t+\Delta t) = \lambda^n q_{cj}(t)$, with $n \sim \mathbb{F}(n)$. $\mathbb{F}(n)$ is a distribution such that:

- multiple step jumps are less likely: increasing difficulty
- Backward firms more likely to multiple jumps:
  advantage of backwardness [à la Gerschenkron (1951)]

Innovation Decision and Industrial Policy

4 main determinants of innovation incentives:

1. **Expansion** to new markets
2. **Defense** of domestic markets
3. **Quality/profit** improvement
4. **Spillovers**

Innovation Decision and Industrial Policy

Policies affect these incentives through different channels:

1. **Tariffs** and the profit channel:

$$\hat{\Pi}\left(q_{jt}|m,\tau^{US},\tau^{FN}\right)=\left(\frac{1-\beta}{(1+\kappa+\tau^{FN})\eta}\right)^{\frac{1-\beta}{\beta}}\beta q_{jt}$$

2. **R&D subsidies** and the cost channel:

$$C\left(x_{mt}^{US}|s^{US}\right)=\left(1-s^{US}\right)\alpha_{US}\left(x_{mt}^{US}\right)^{\gamma_{US}}q_{jt}$$

▸ VFs

Quantitative Analysis

Part 1. Estimation

Calibration strategy

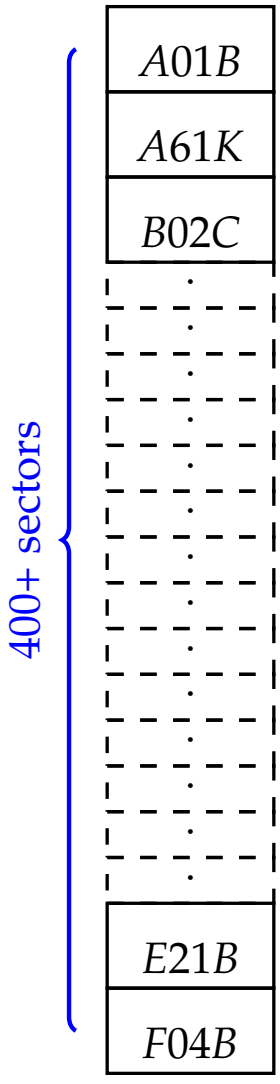
- 17 parameters to be determined, 7 are estimated
  - 6 statistics on trade, growth, and innovation over 1975-81 ...
  - and the leadership distribution in 1981.

TABLE: Model fit

Moment	Estimate	Target	Source
1. TFP Growth U.S.	0.45%	0.55%	Coe et al. (2009) 1975-81
2. TFP Growth FN	2.13%	1.82%	Coe et al. (2009) 1975-81
3. R&D/GDP U.S.	1.65%	1.75%	OECD 1981
4. R&D/GDP FN	1.85%	1.96%	OECD 1981
5. Entry Rate U.S.	10%	10%	BDS 1977-81
6. Export Share U.S.	7.11%	7%	WB 1975-81
7. Tech Gap Distribution	n/a	n/a	See next slide.

ext

Patent Classes to Technology Gaps



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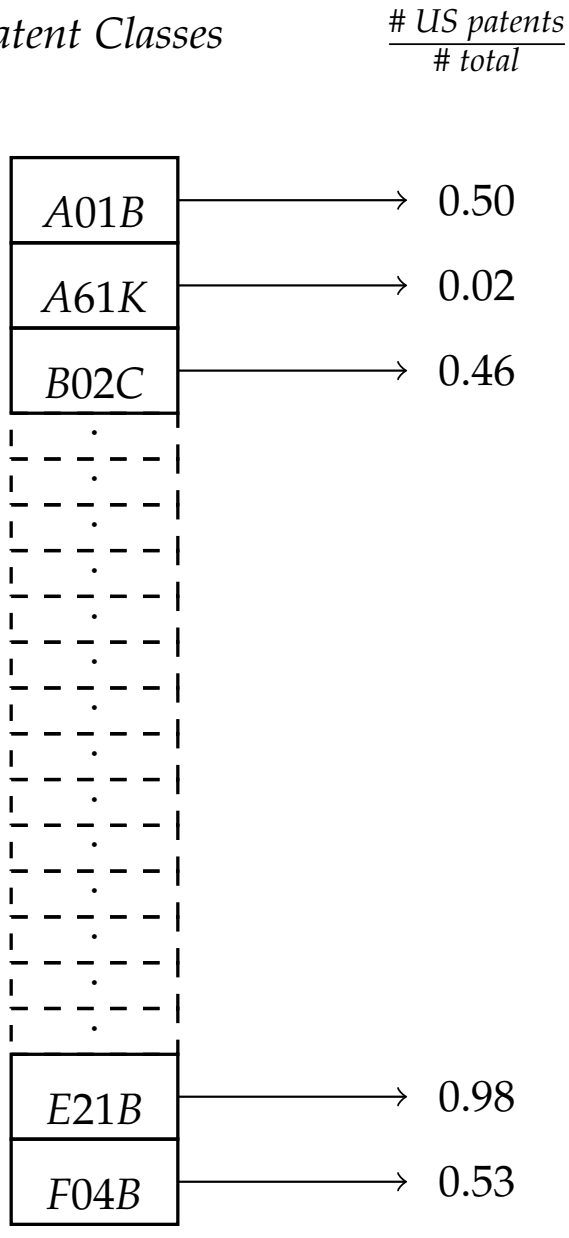

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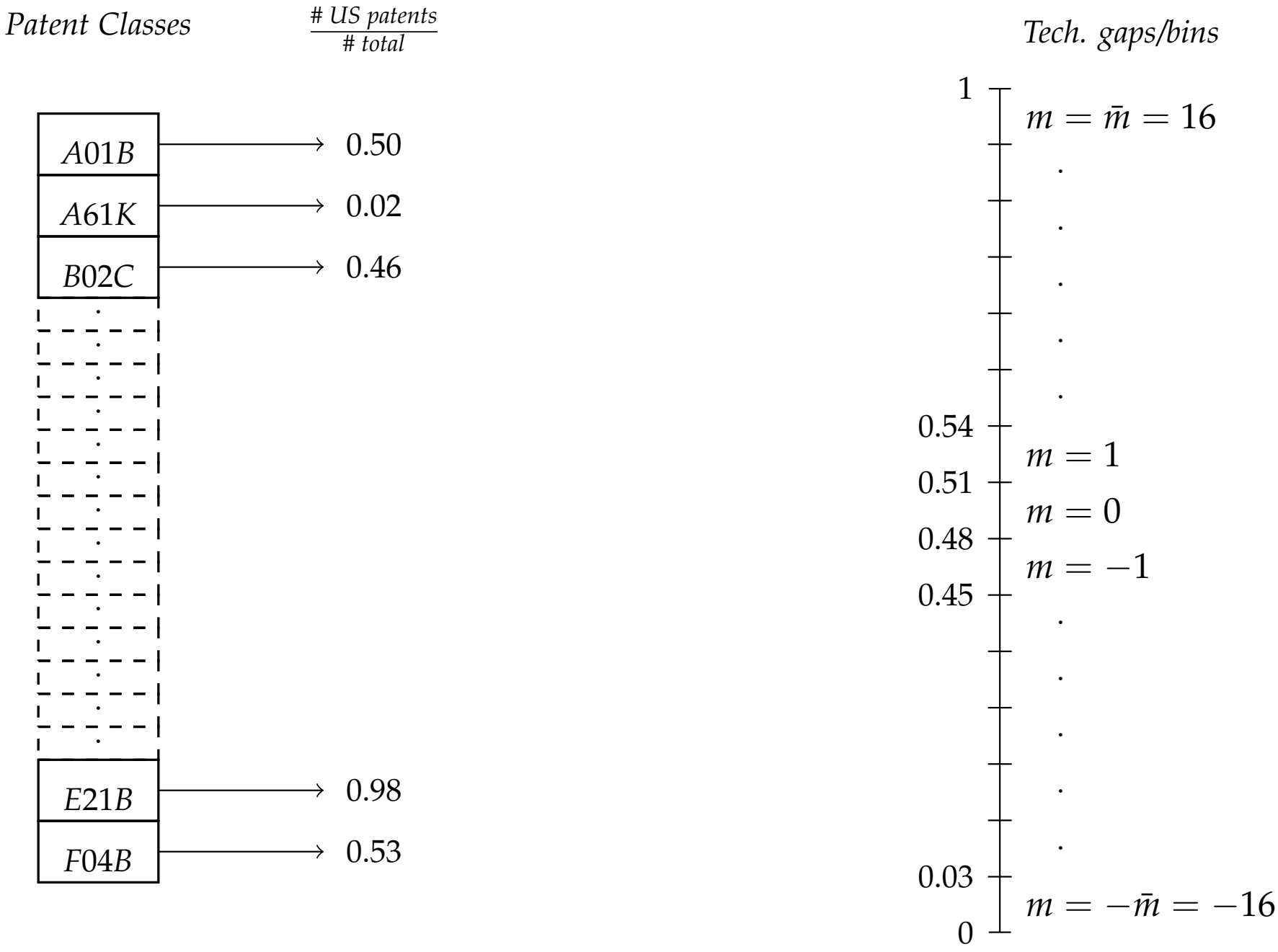

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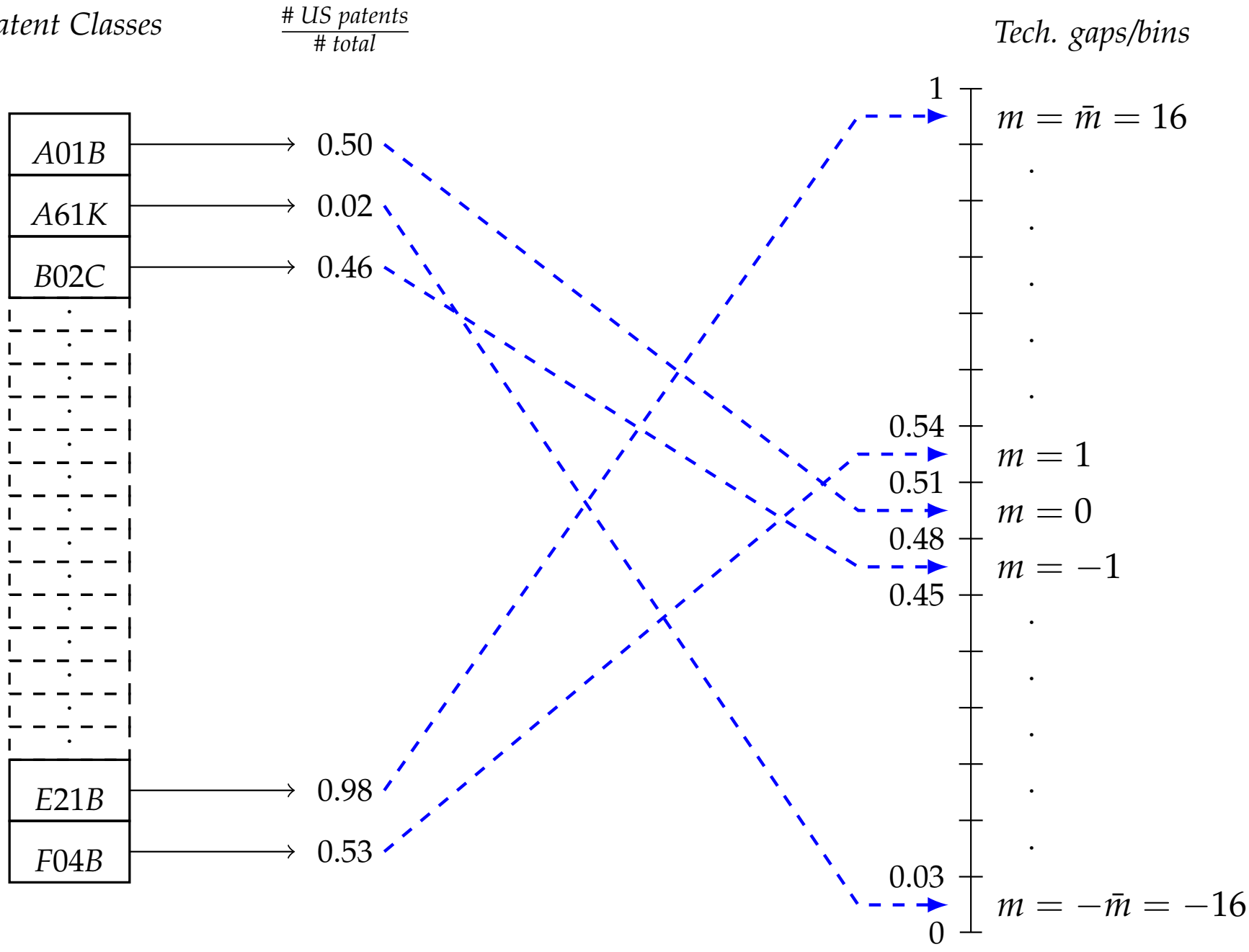
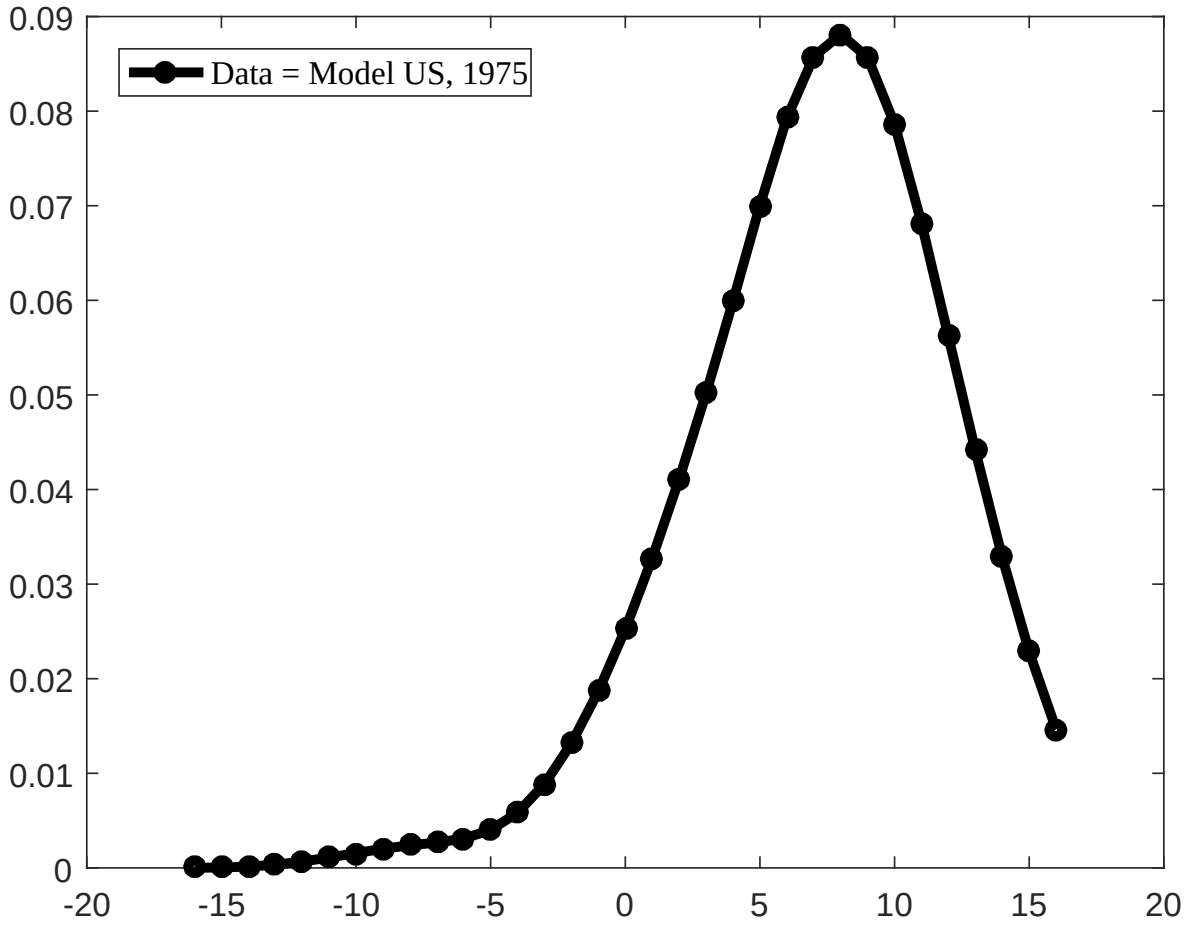


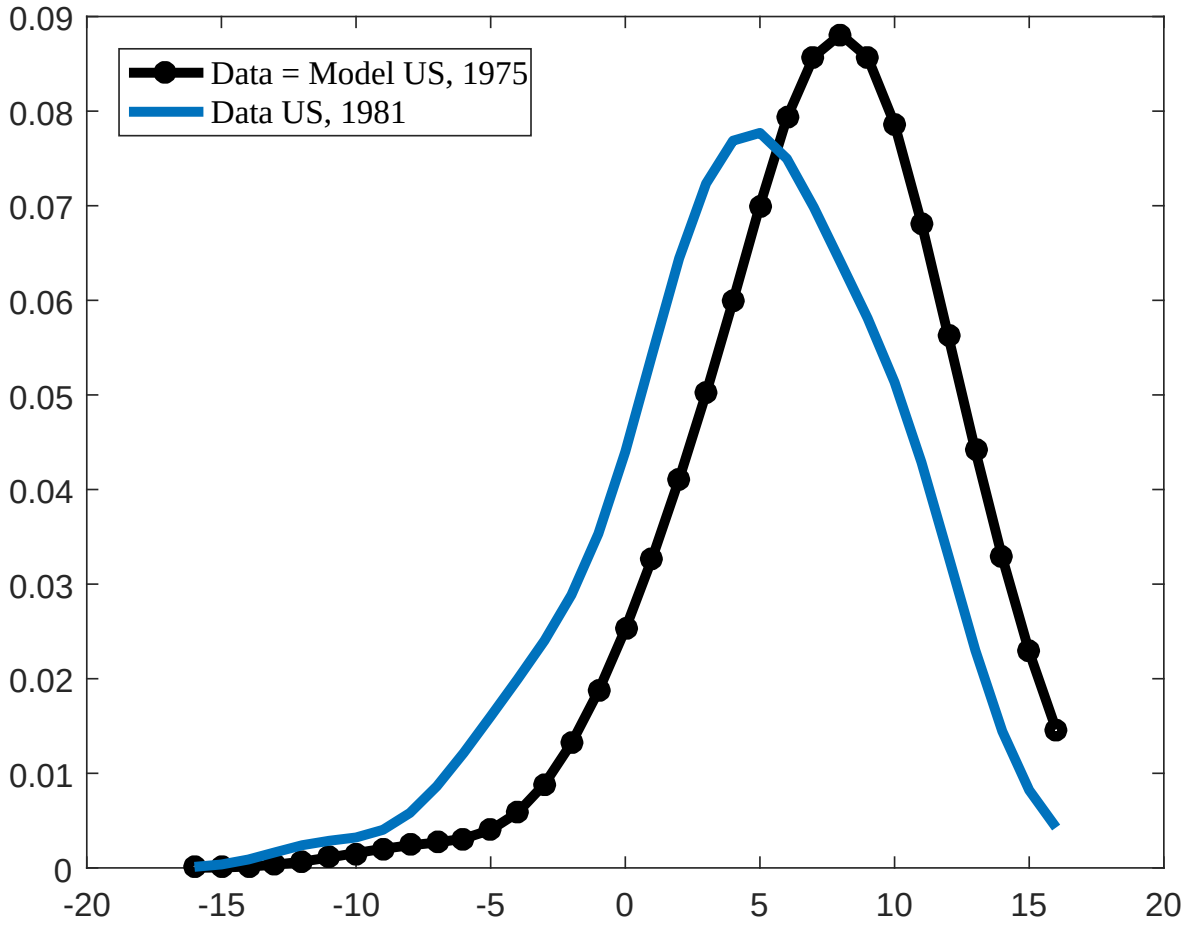
Identification: Evolution of Sector Shares

- Initiate the model in 1975 feeding in the leadership distribution ...



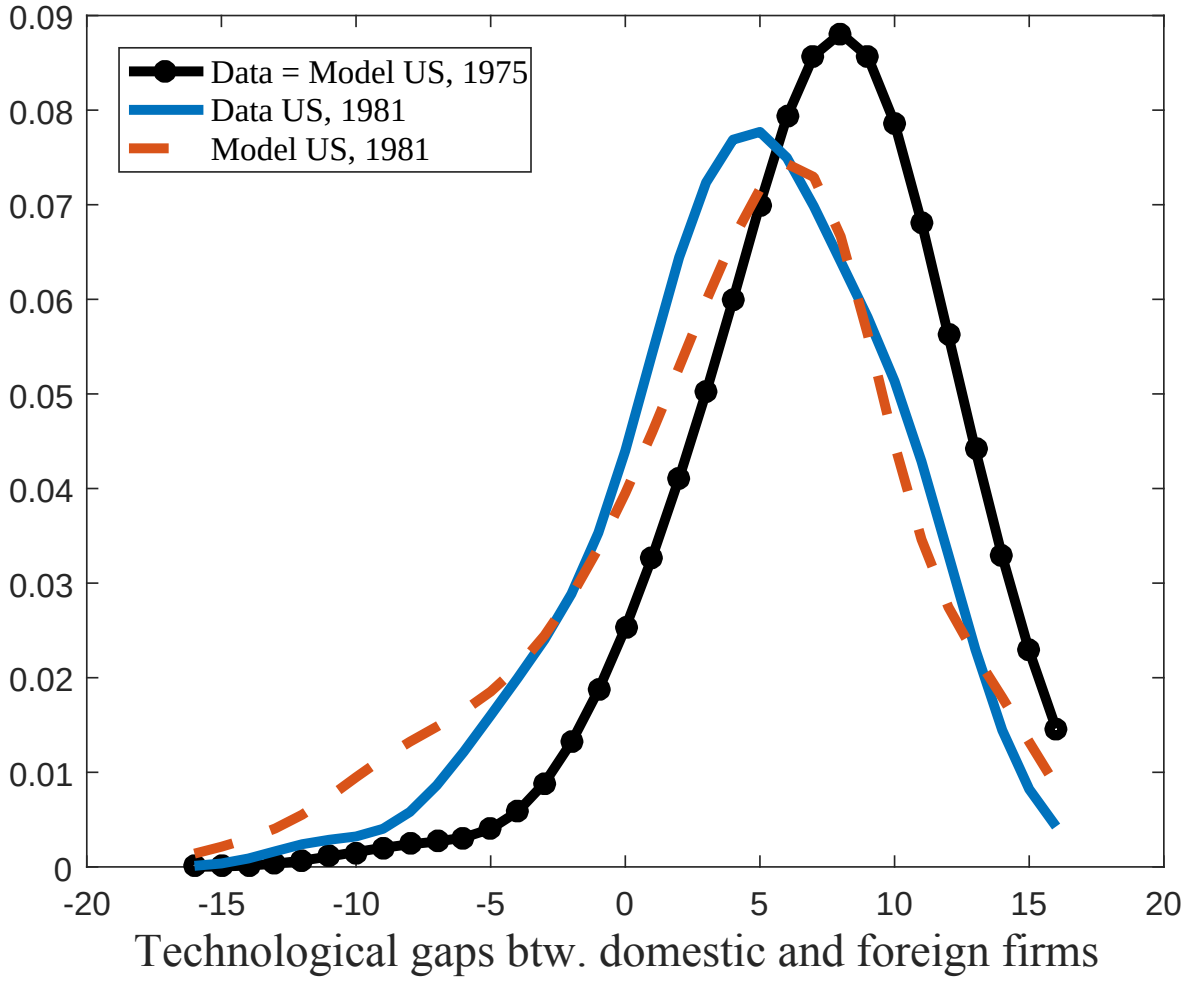
Identification: Evolution of Sector Shares

- ... and simulate until 1981.



Identification: Evolution of Sector Shares

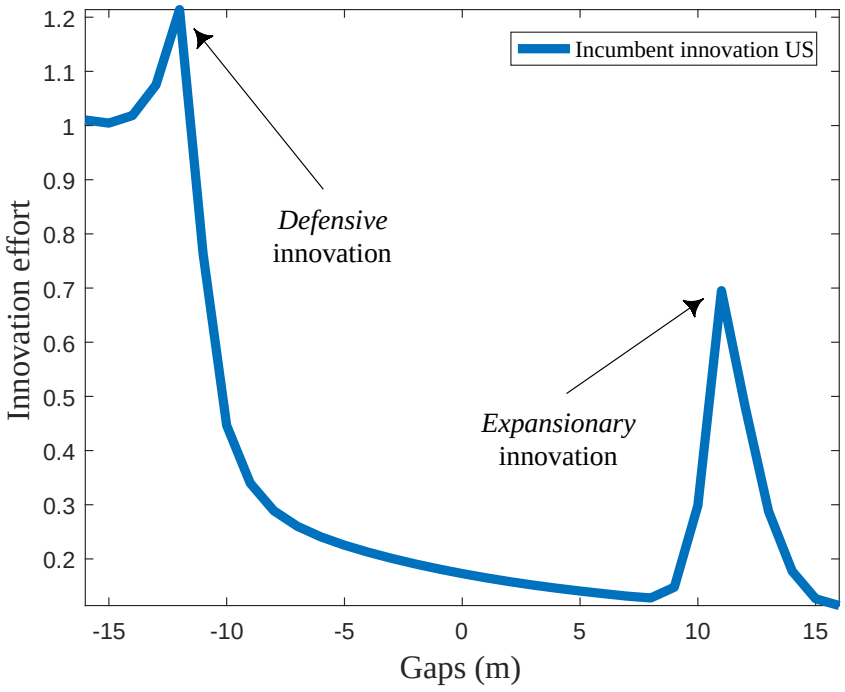
⇒ Model replicates the adverse shift of leadership distribution toward smaller gaps over 1975-85.



Quantitative Analysis

Part 2. Validation of the Model

Validation I: Steady-state Innovation Distribution



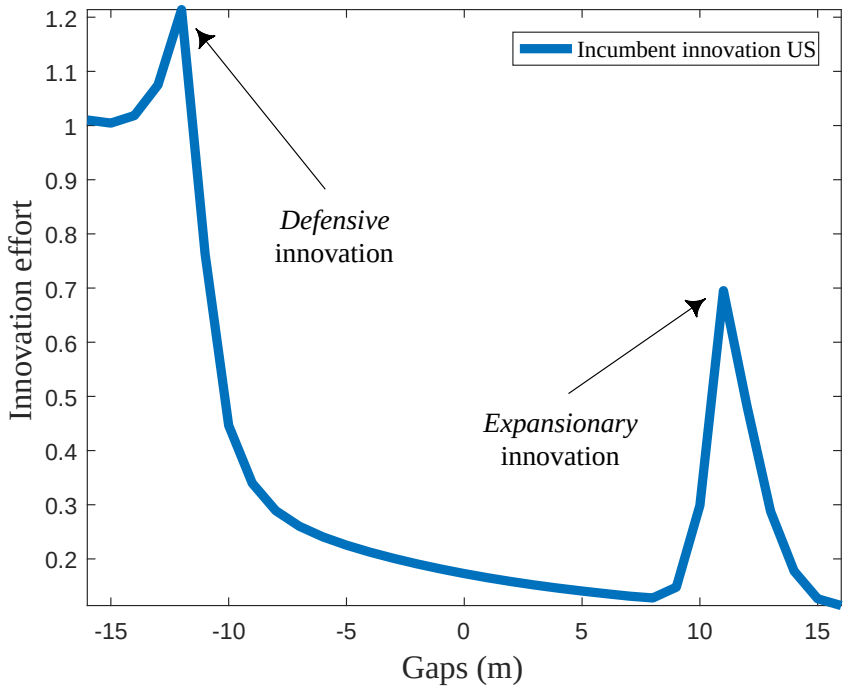
A) Model

FIGURE: Incumbent innovation effort and leadership

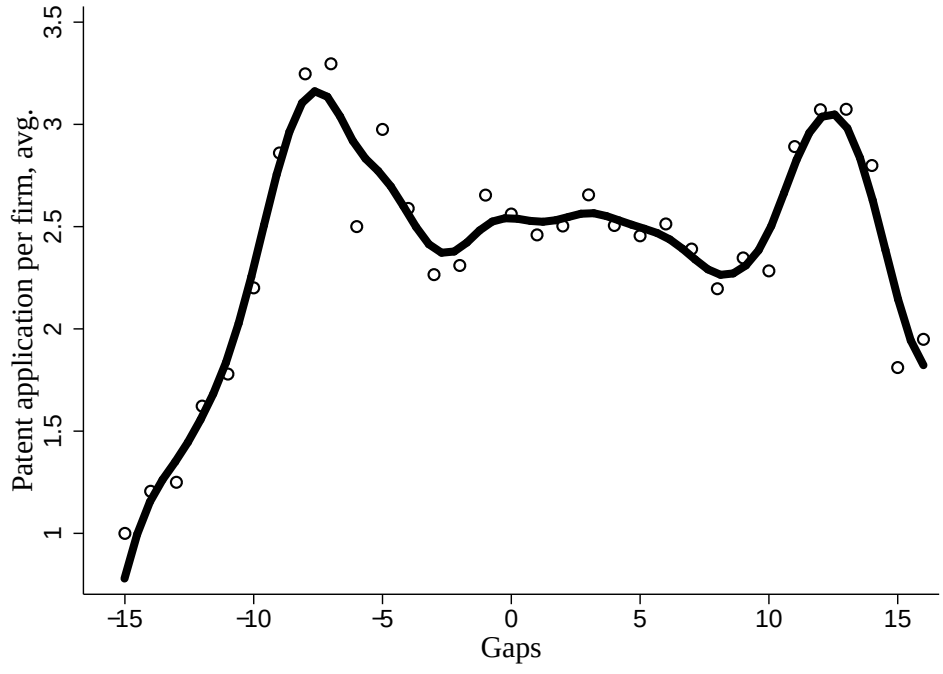
In our simulation, estimated $m^* = 11$.

ces raw

Validation I: Steady-state Innovation Distribution



A) Model



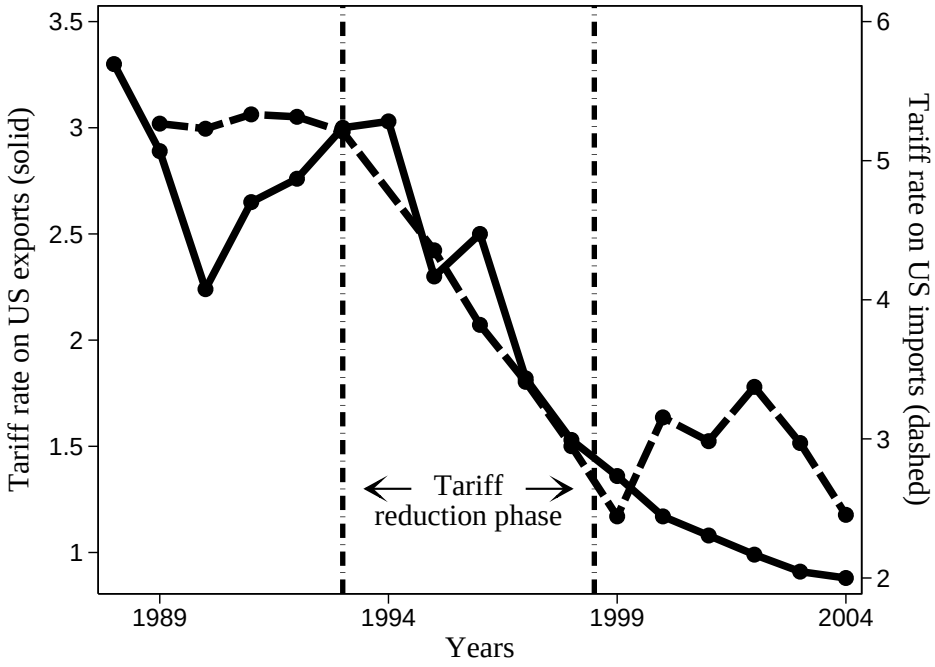
B) Data

FIGURE: Incumbent innovation effort and leadership

In our simulation, estimated $m^* = 11$.

▸ ces ▸ raw

Validation II: Trade Cost Reduction

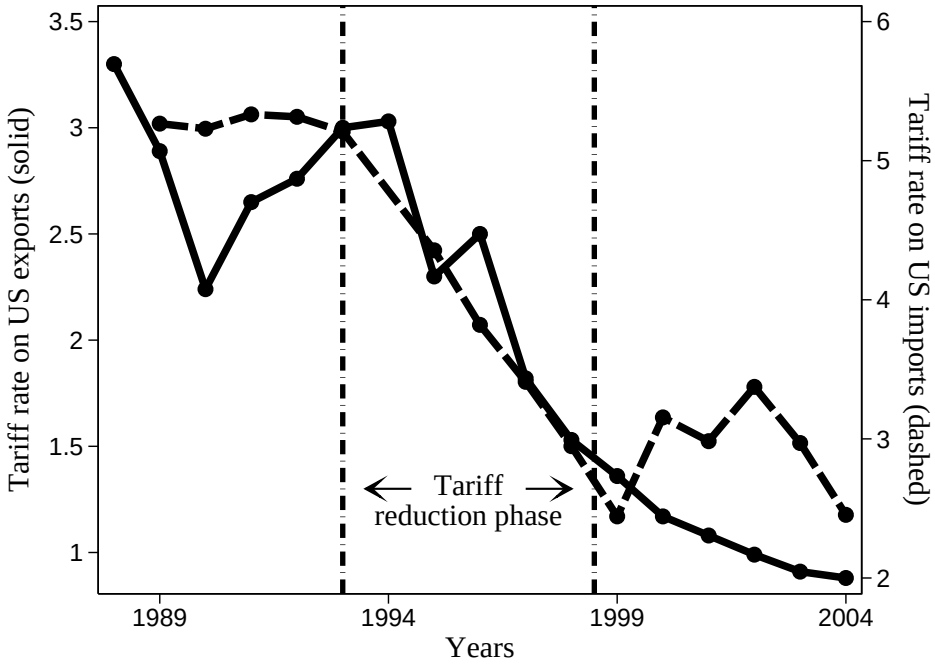


A) Tariffs

FIGURE: Tariffs and incumbents' innovation intensity in manufacturing

Data support the model prediction: lower trade barriers make the peaks shift inward.

Validation II: Trade Cost Reduction



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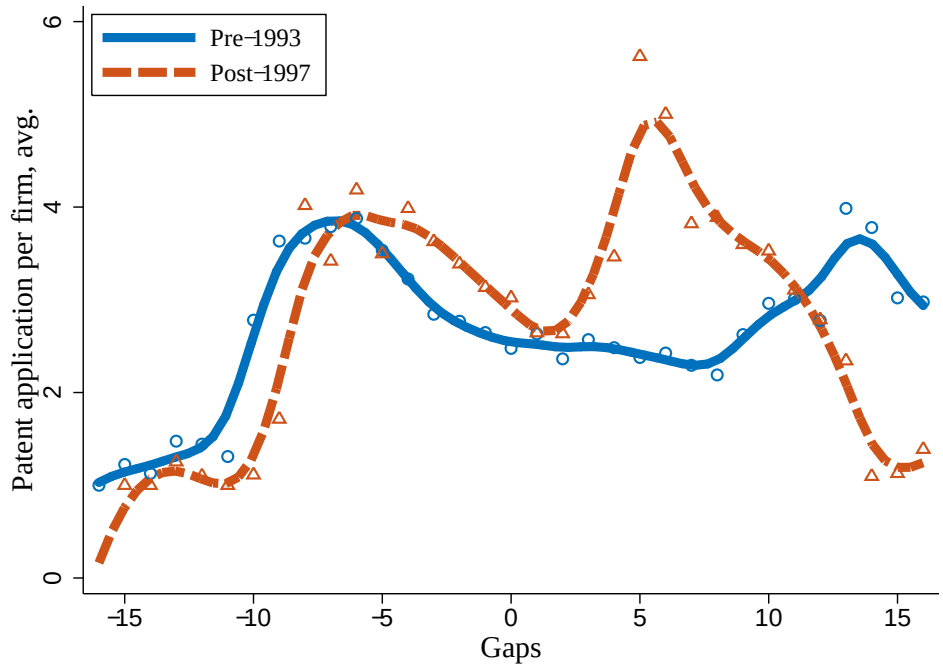
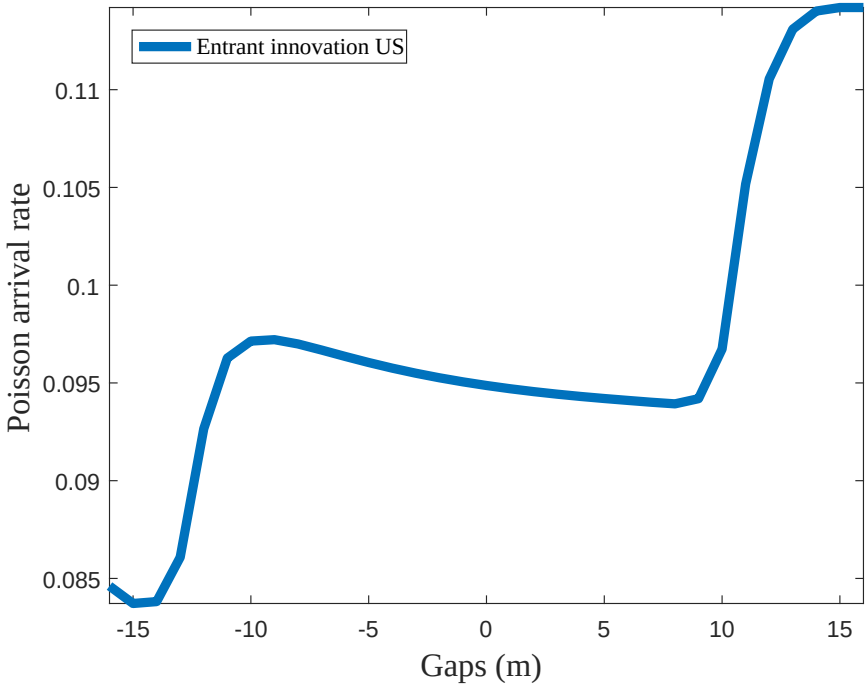


B) Incumbent innovation intensity

FIGURE: Tariffs and incumbents' innovation intensity in manufacturing

Data support the model prediction: lower trade barriers make the peaks shift inward.

Validation III: Implications on Entrant Innovation



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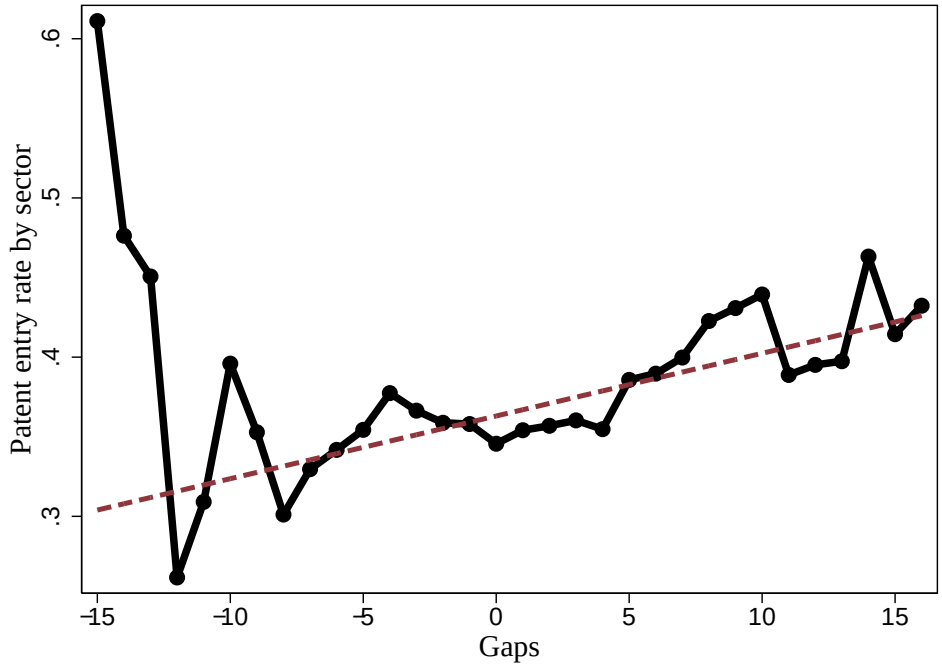

B) Data

FIGURE: Entrant innovation effort and leadership

valid4

Quantitative Analysis

Part 3. Welfare Implications and Optimal Policy

Welfare Effects of Catching-Up

TABLE: Observed and optimal U.S. R&D subsidy: 1981-2016

	Subsidy rate	Welfare gains 1981-2016
Observed R&D subsidy	19.2%	0.87%
Optimal R&D subsidy	66%	5.49%

Welfare Effects of Catching-Up

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*Observed policy is optimal when a horizon of only **5 years** considered.*

Welfare Effects of Protectionist Policies

Q1. What is the effect of a 20% increase in tariffs on welfare?

Q2. What is the effect of a 20% increase in tariffs on innovation?

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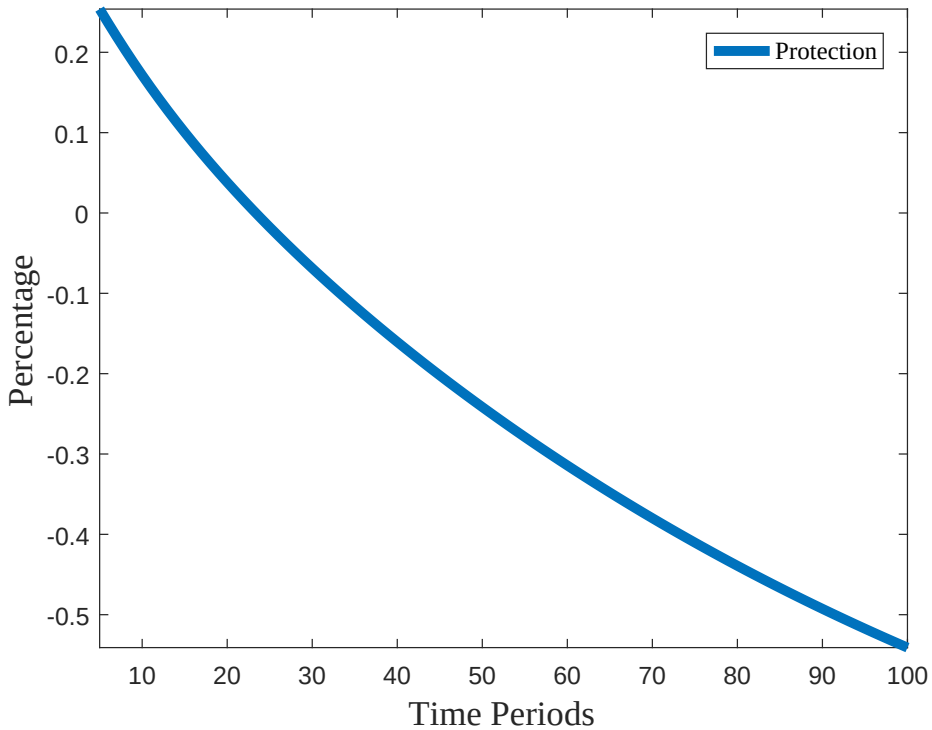

A) Consumption equivalent welfare

One-sided tariff generates welfare gains in the short-run ($<$ 20 years) and welfare losses in longer horizons.

foreign

Welfare Effects of Protectionist Policies

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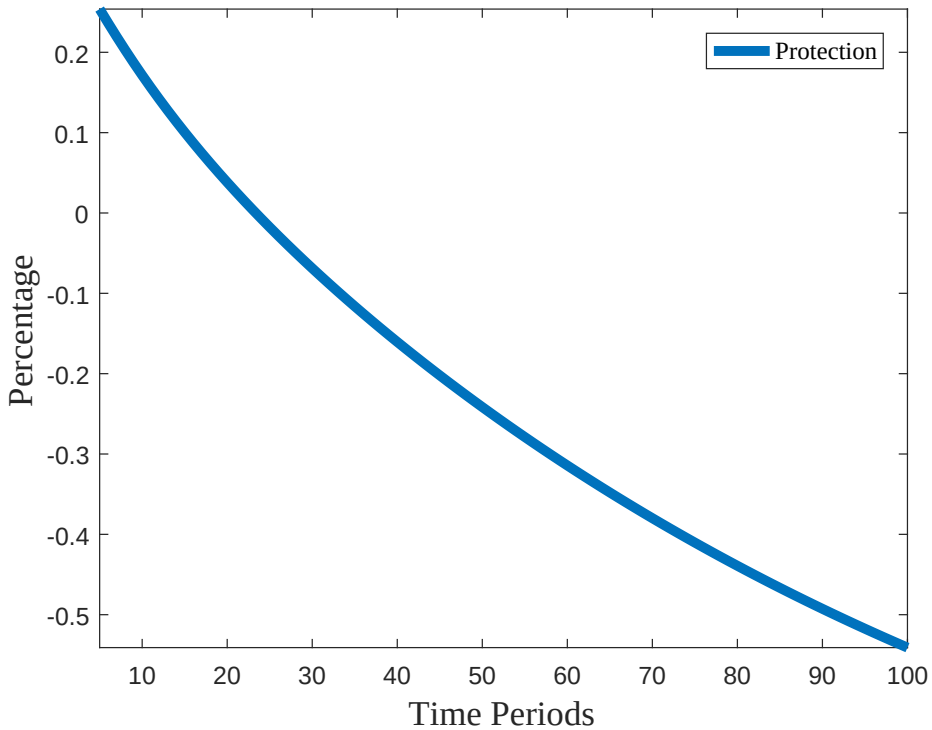

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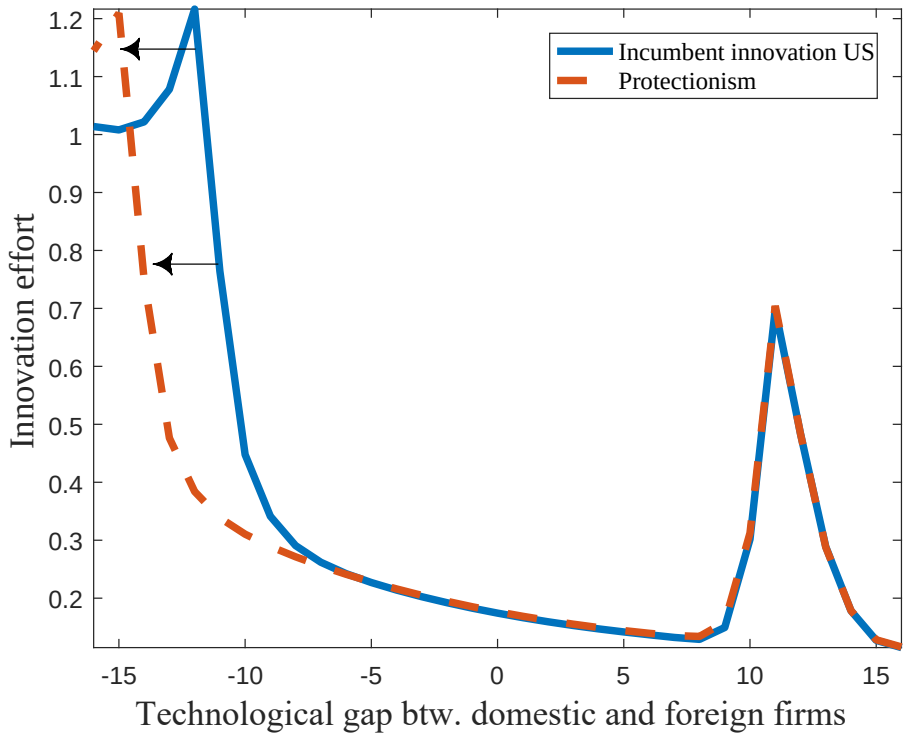

B) Innovation response of incumbents

This is due to reduced defensive innovation incentives.

foreign

Welfare Effects of Protectionist Policies

Q1. What is the optimal tariff rate for different time horizons?

Welfare Effects of Protectionist Policies

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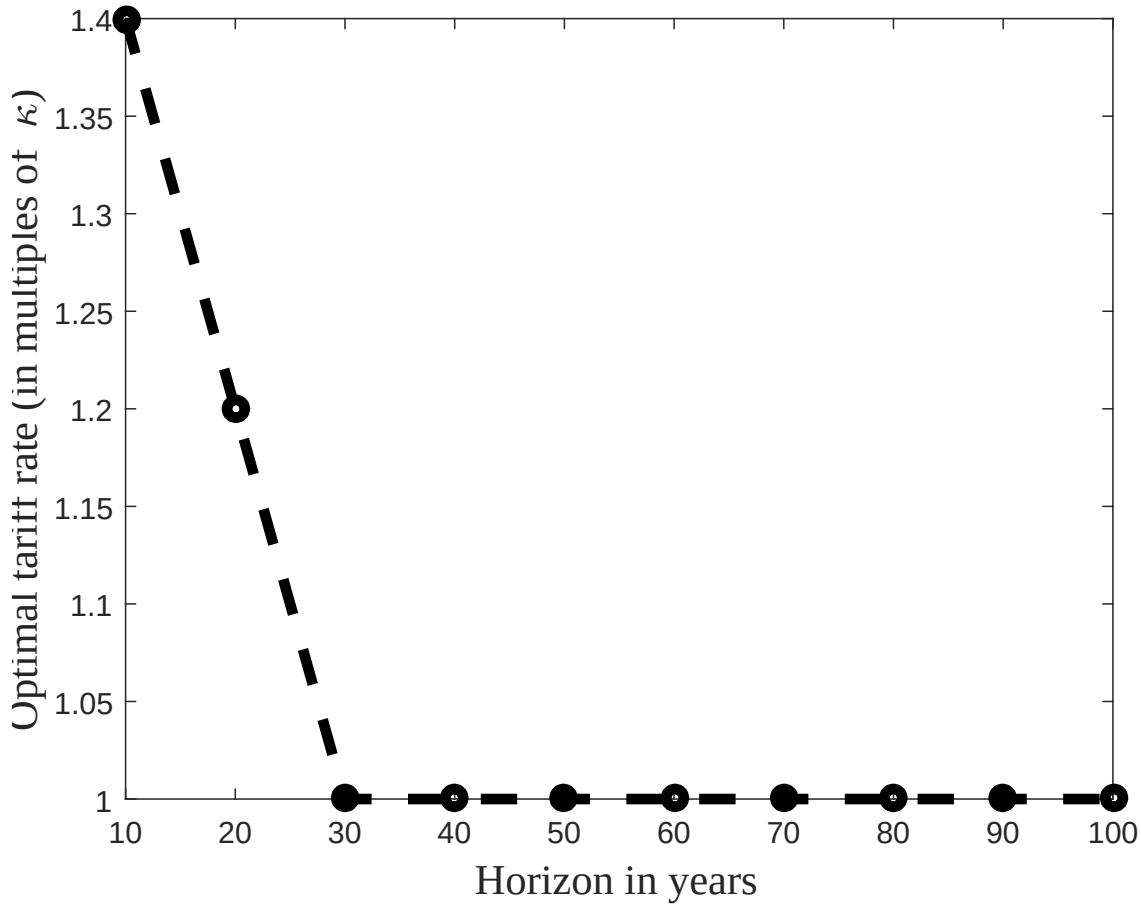

Status quo is optimal if the policy horizon is $\approx$ 25 years.

retal

Optimal Subsidy Policy

Q1. What is the optimal subsidy rate for different time horizons?

Q2. How does it depend on the degree of openness?

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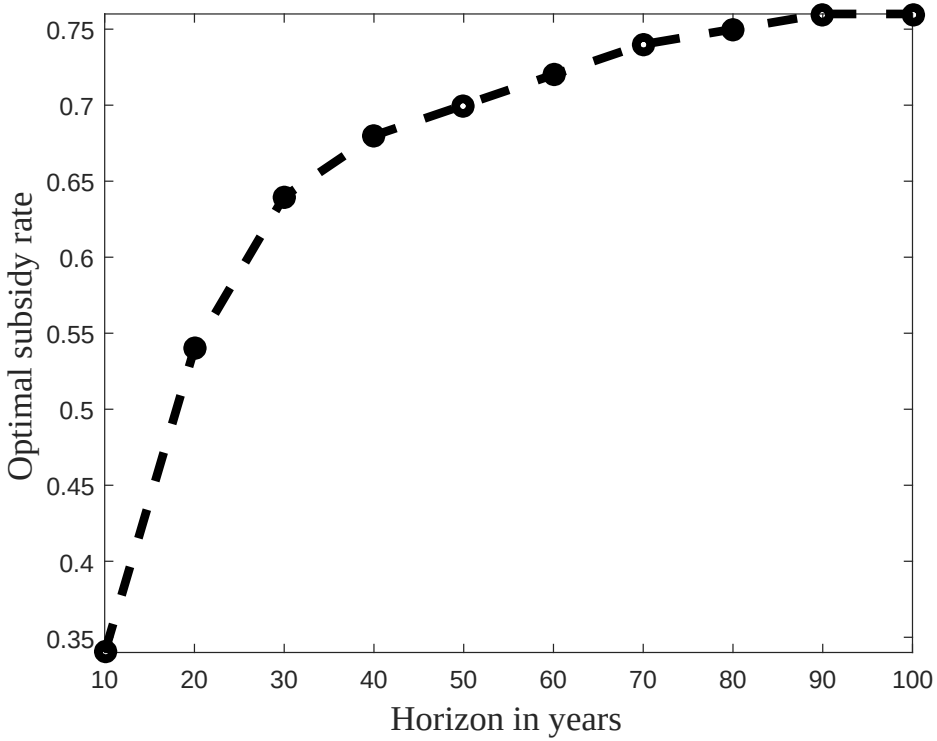

A) Over different horizons

The longer the policymaker's horizon is, the more aggressive is the optimal policy.

dep

Optimal Subsidy Policy

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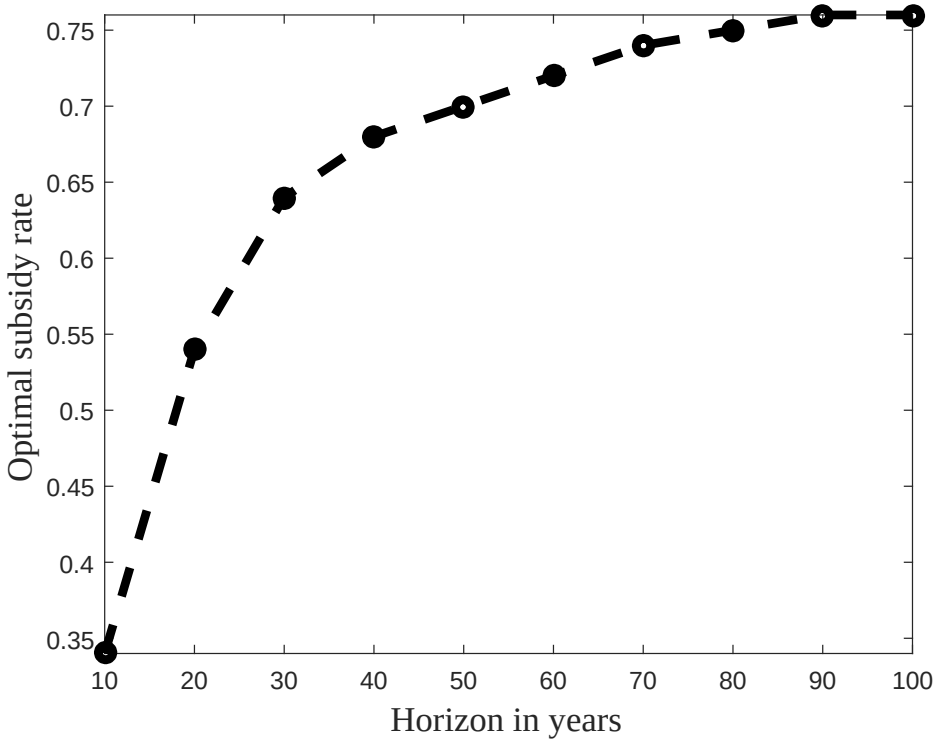
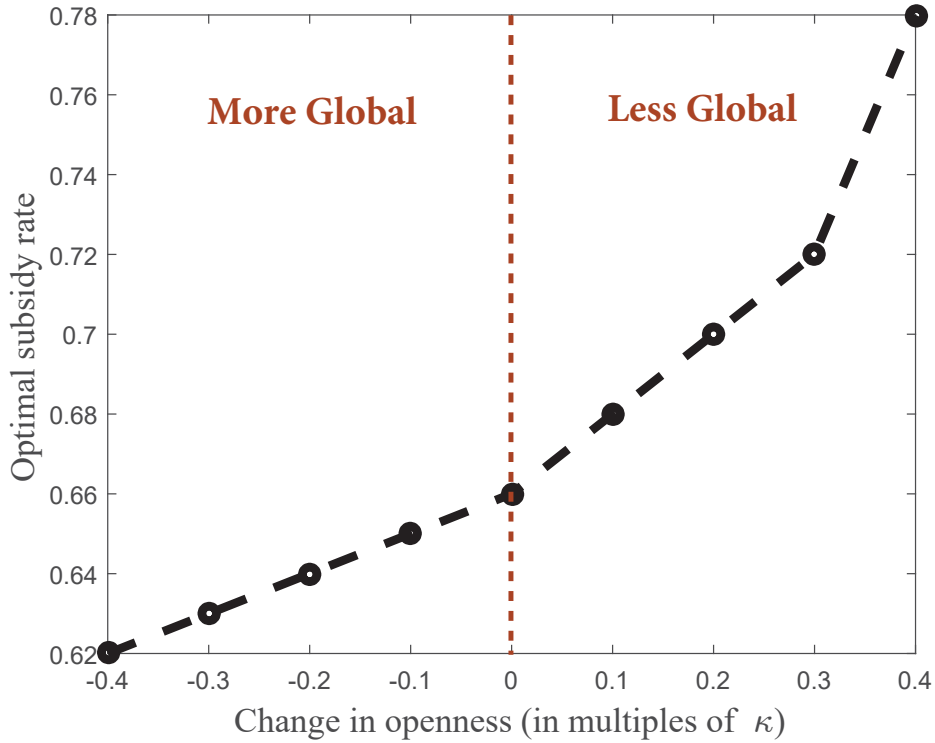
Q2. How does it depend on the degree of openness?



A) Over different horizons



B) Over openness (fixed horizon of 35 years)

The more open the world markets are, the less aggressive is the optimal policy.

dep

Extensions and Robustness

- Quantifying the welfare impact of protectionism on foreign country.
- Optimal policy mix.
- Effect of retaliation.
- Labor in the intermediate good production.
- Tariff revenue consumed by the household.
- Alternative values for $\bar{m}$.

Conc

Quantitative Analysis

Part 4. Impact of Import Competition on Incumbent Innovation

Import Competition and Innovation

The empirical literature on trade and innovation has documented conflicting (!) results:

Import ↑ innovation

- Bloom, Draca, and Van Reenen (2016),
- Gorodnichenko, Svejnar, and Terrell (2010),
- Iacovone (2012),
- Coelli, Moxnes, and Ulltveit-Moe (2016),
- Fernandes (2007)

Import ↓ innovation

- Autor, Dorn, Hanson, Pisano, and Shu (2016)
- Gilbert (2006),
- Hashmi (2013),
- Hombert and Matray (2015),

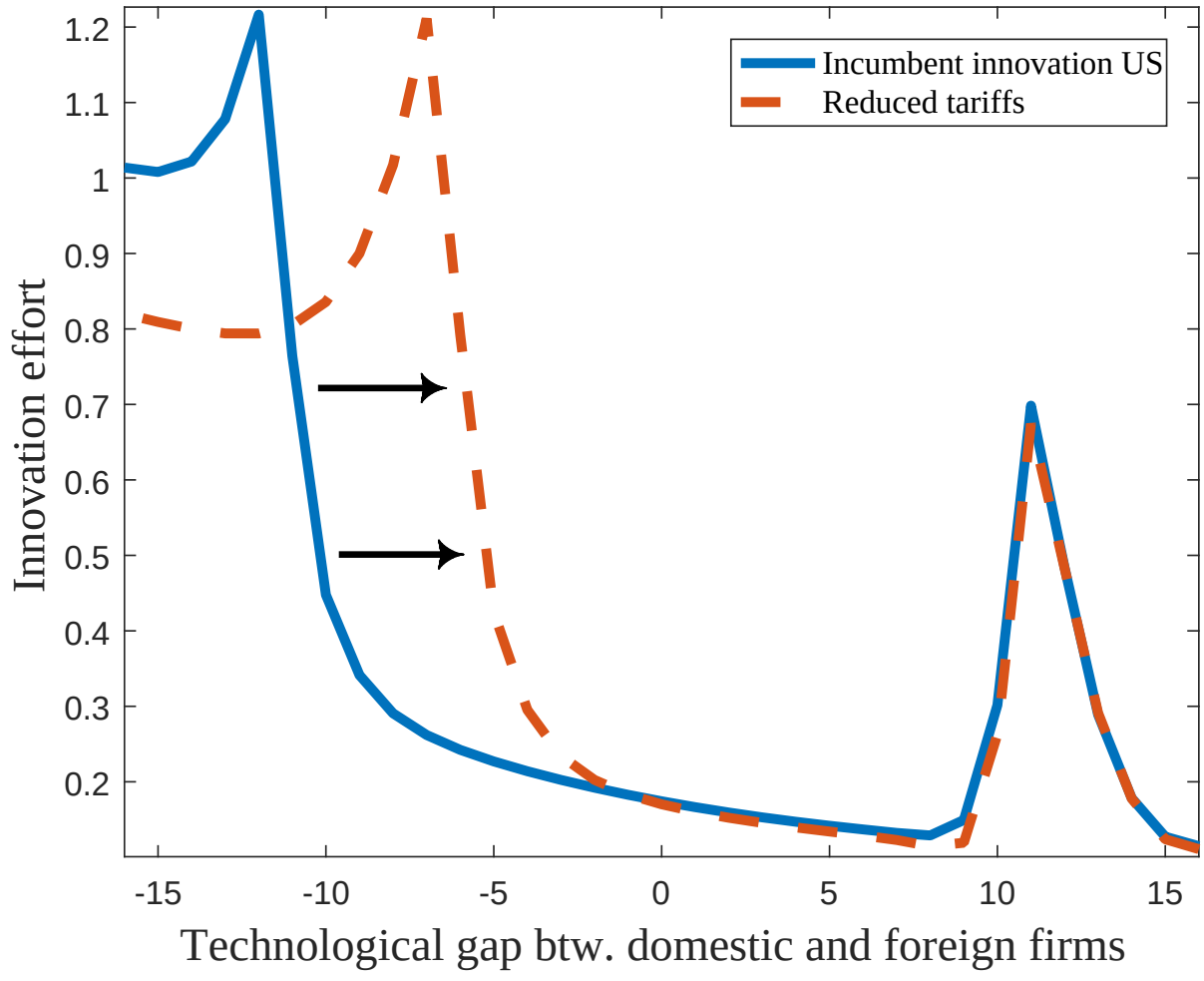
Mixed results

- Chen and Steinwender (2016)
- Aghion, Bergeaud, Lequien, and Melitz (2017)
- Bombardini, Li, and Wang (2017).

How does our model reconcile these?

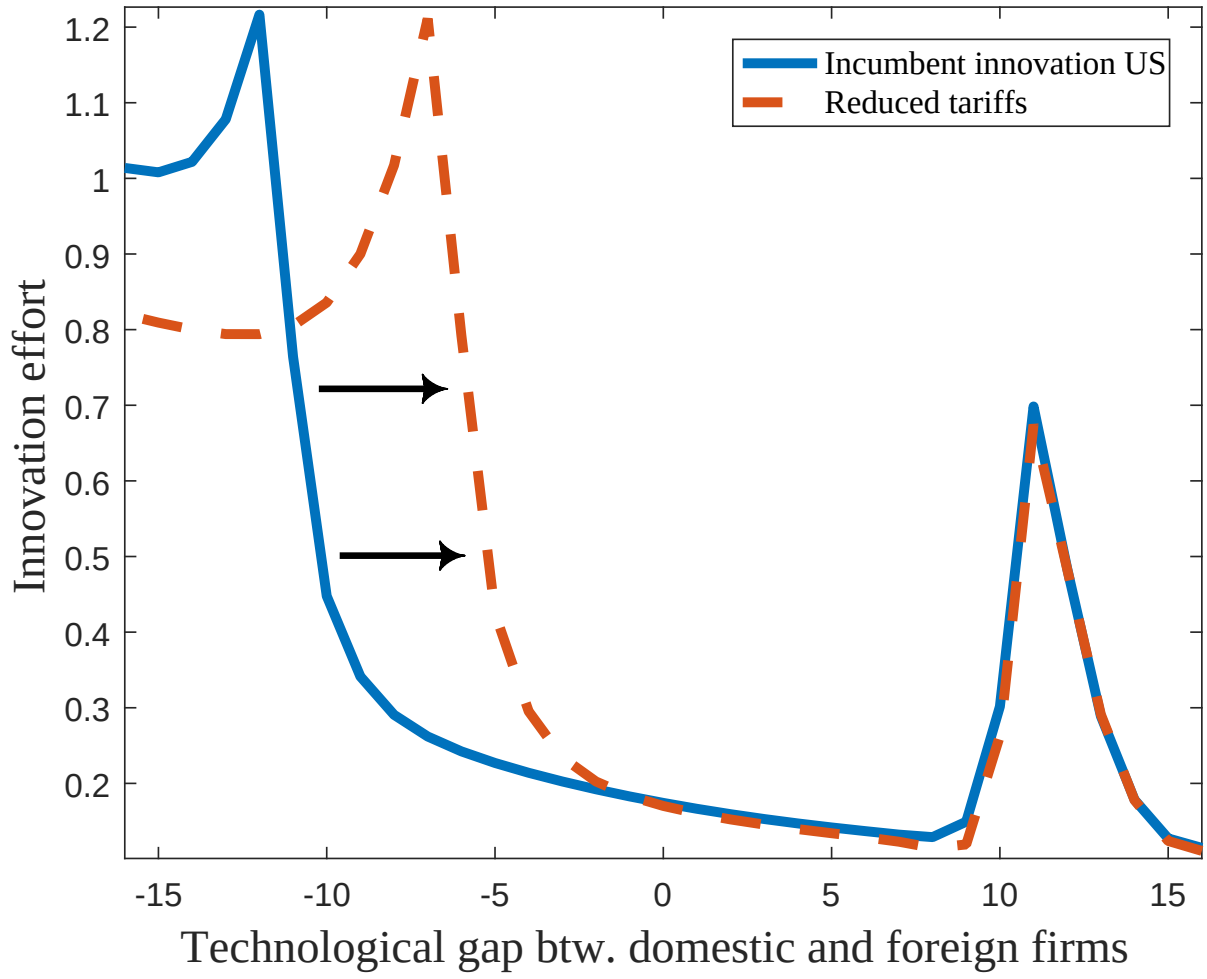
- How can our model speak to these conflicting results?
- Assume a 50% one-sided reduction in tariffs.
- This increases competition on the import margin ...
- ... and changes the sectors that face intensified competition.

50% Reduction in Tariffs



Innovation: reduction in most laggard sectors, increase in less inferior ones

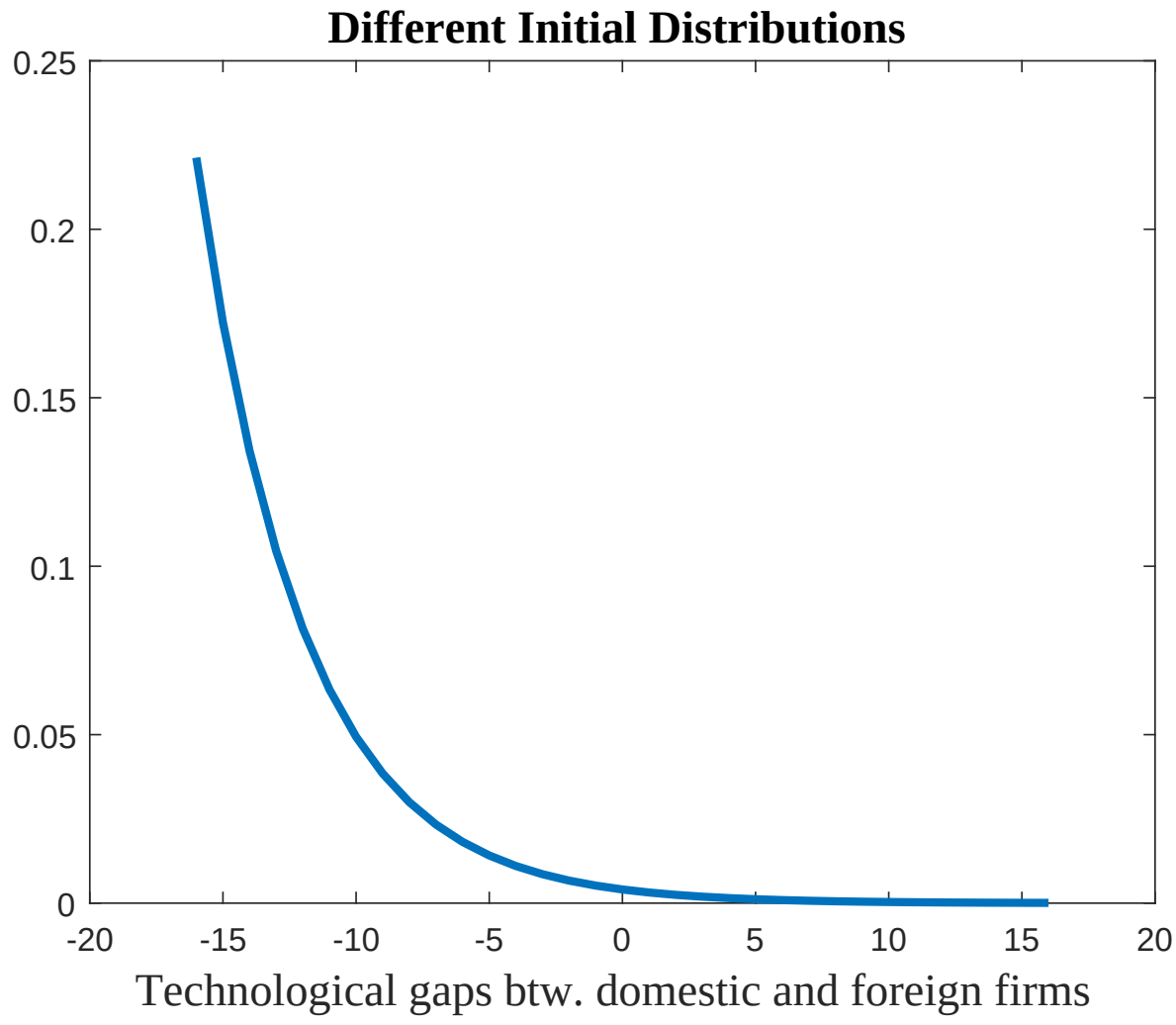
50% Reduction in Tariffs



Innovation: reduction in most laggard sectors, increase in less inferior ones

$\Rightarrow$ *Sectoral composition matters for the overall effect on innovation!*

How does our model reconcile these?



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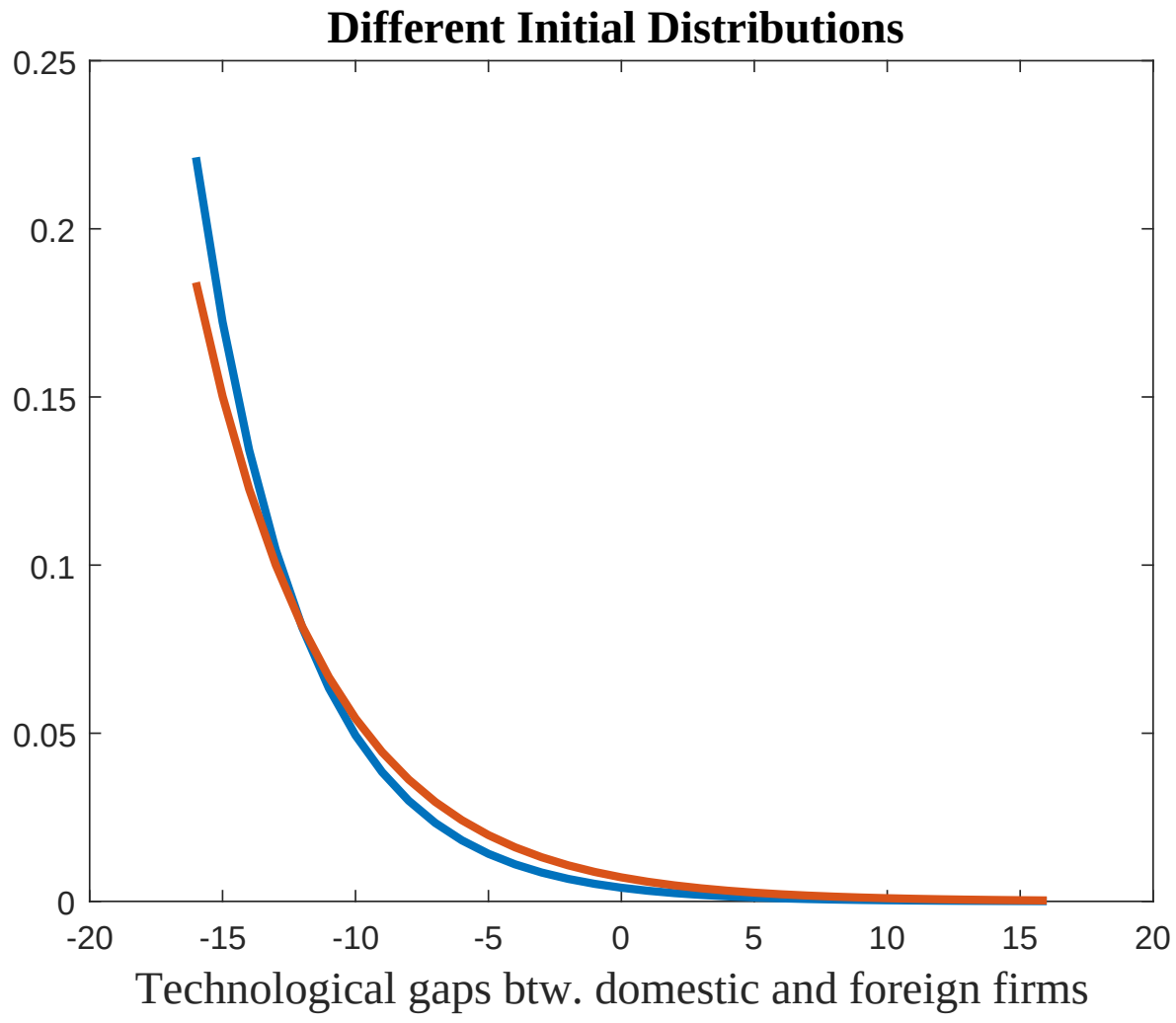

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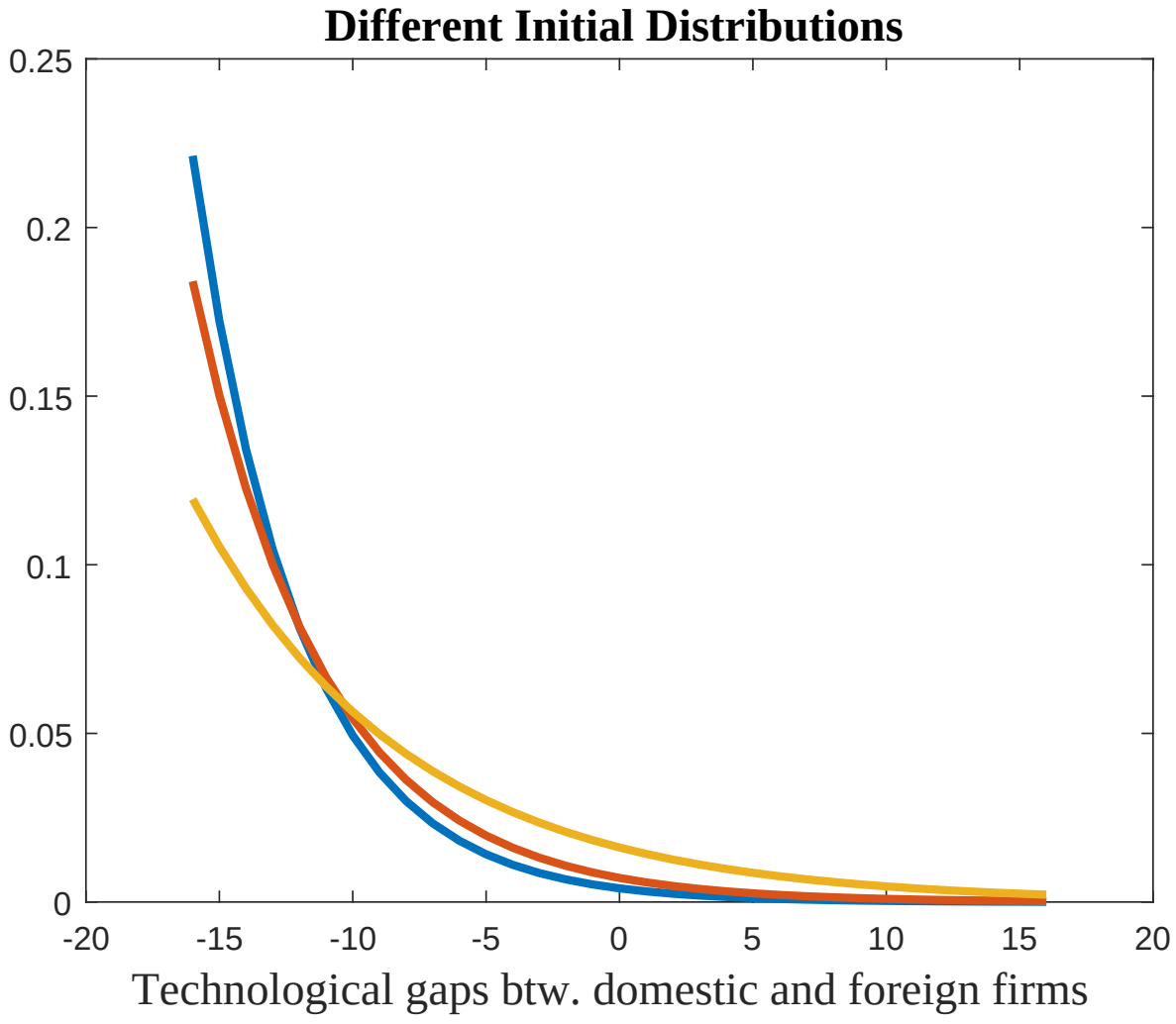

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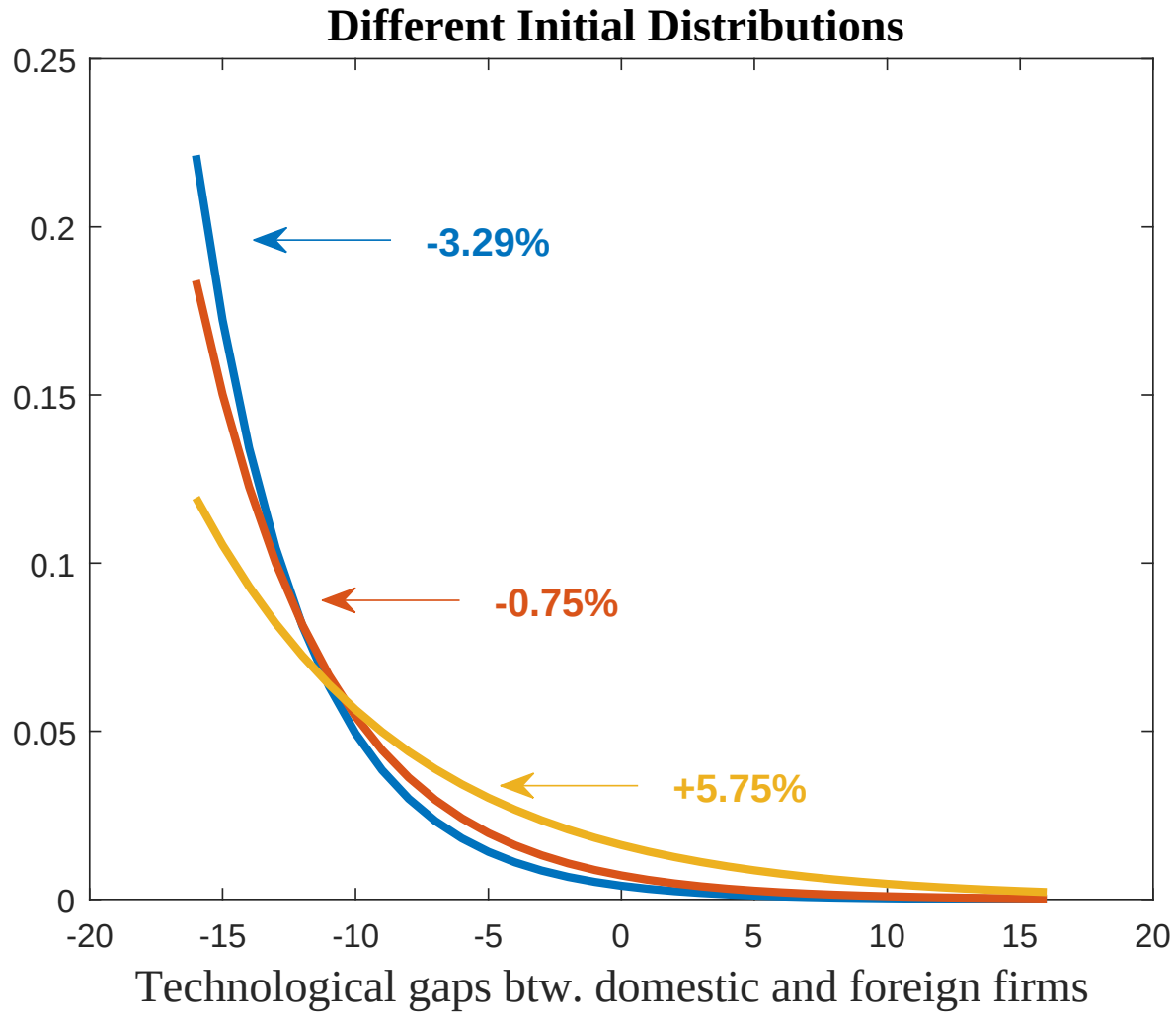
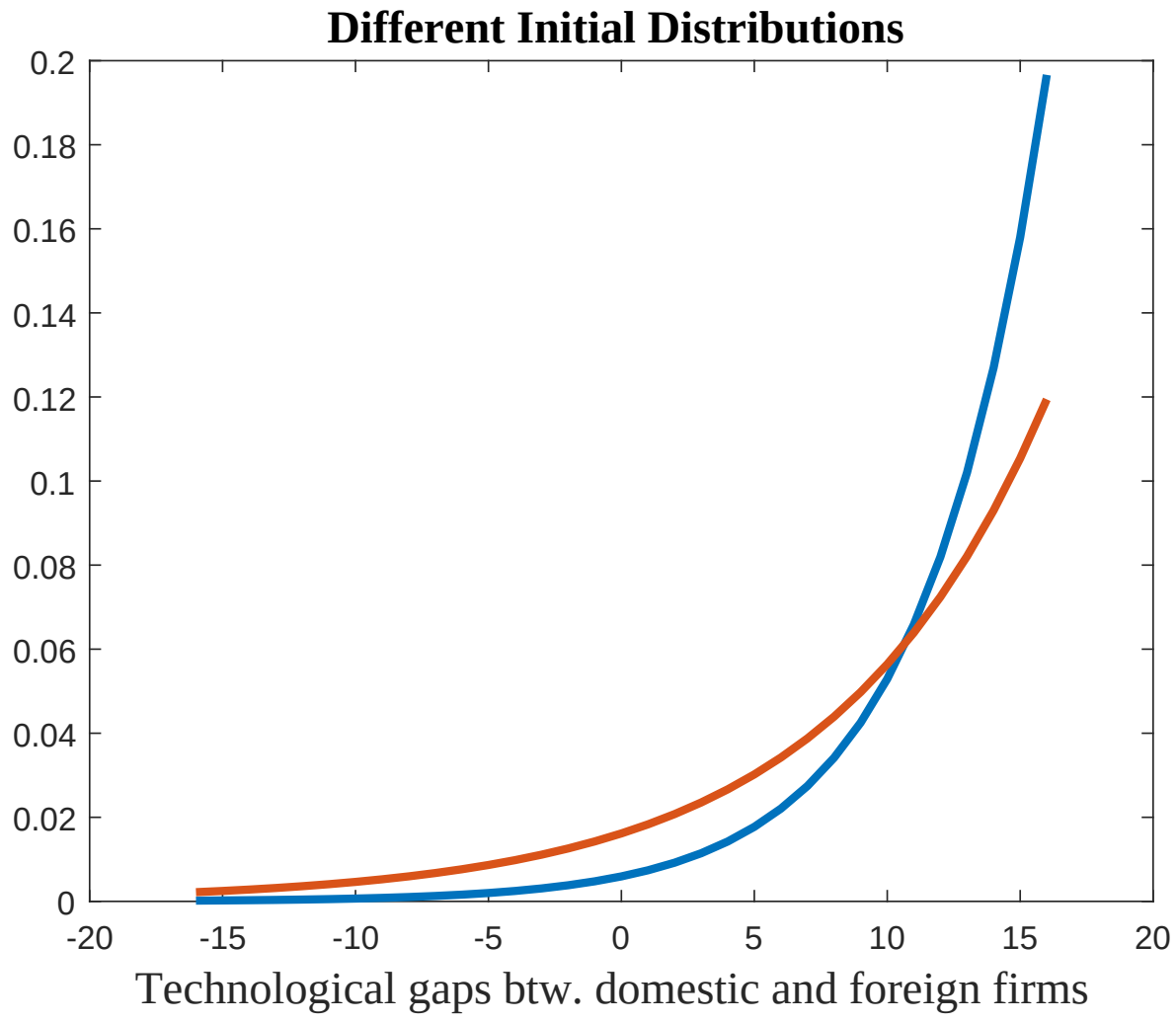


More innovation gains for more advanced economies?

How does our model reconcile these?



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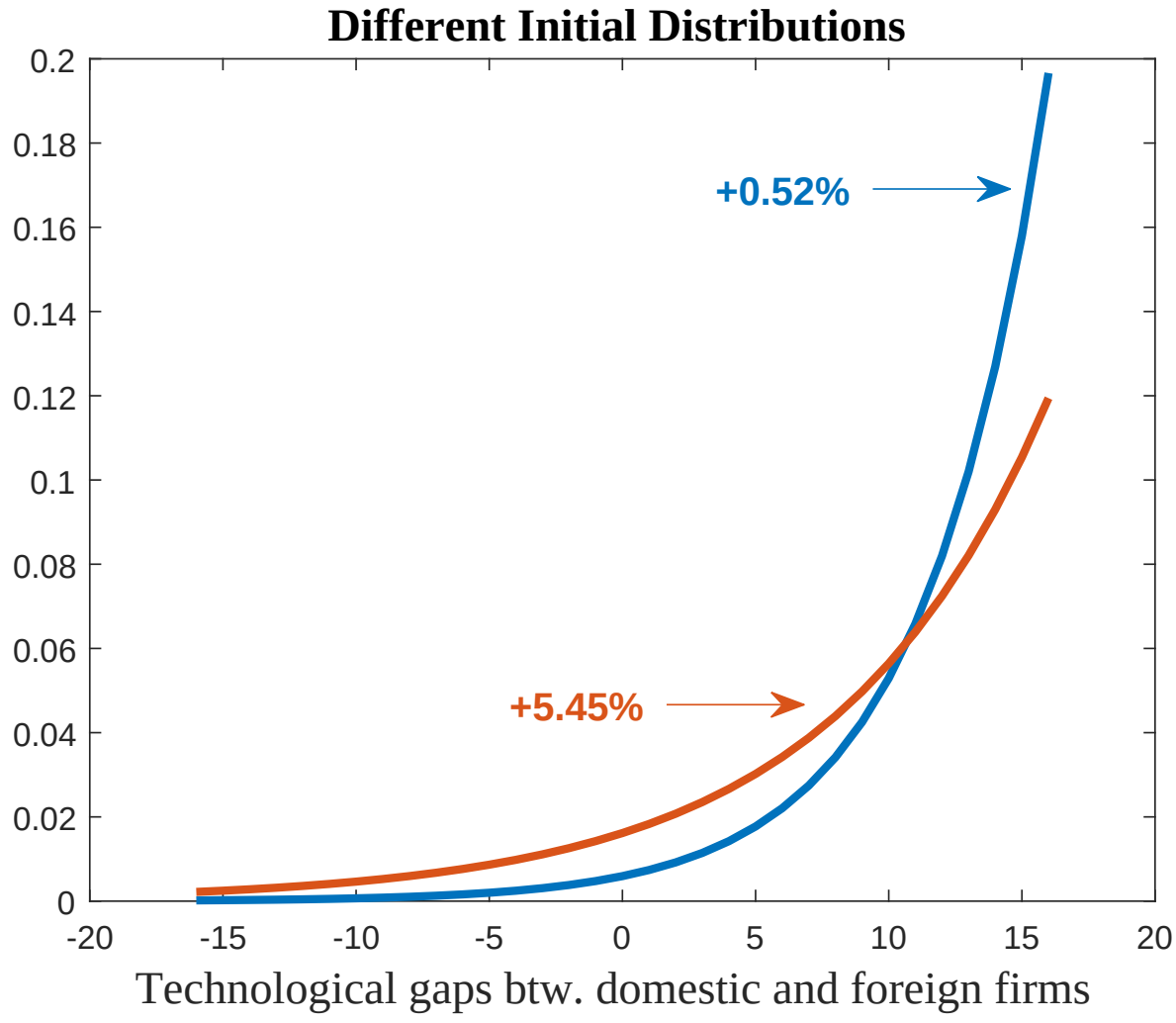
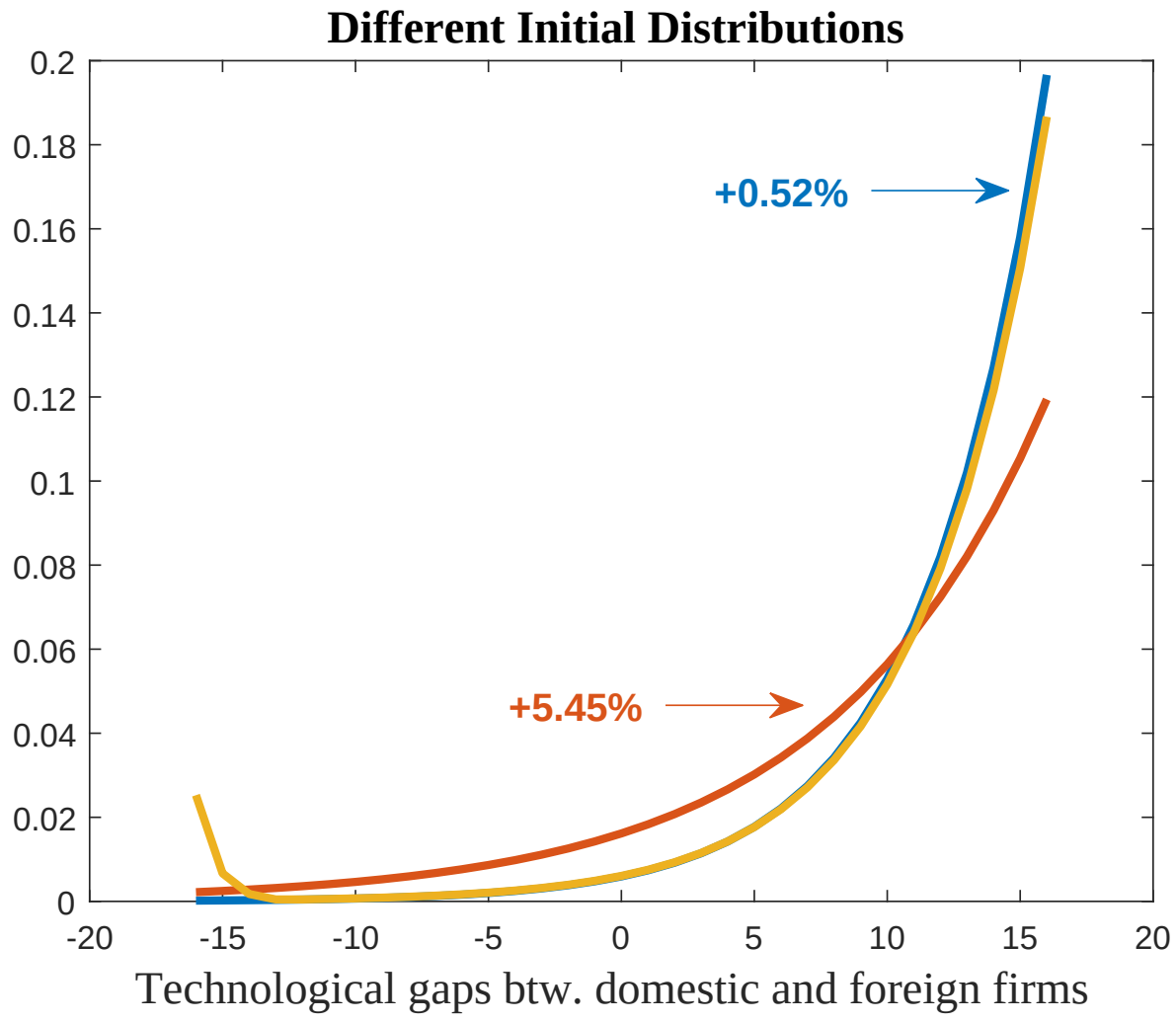


Not necessarily! It depends on the sectoral composition.

How does our model reconcile these?



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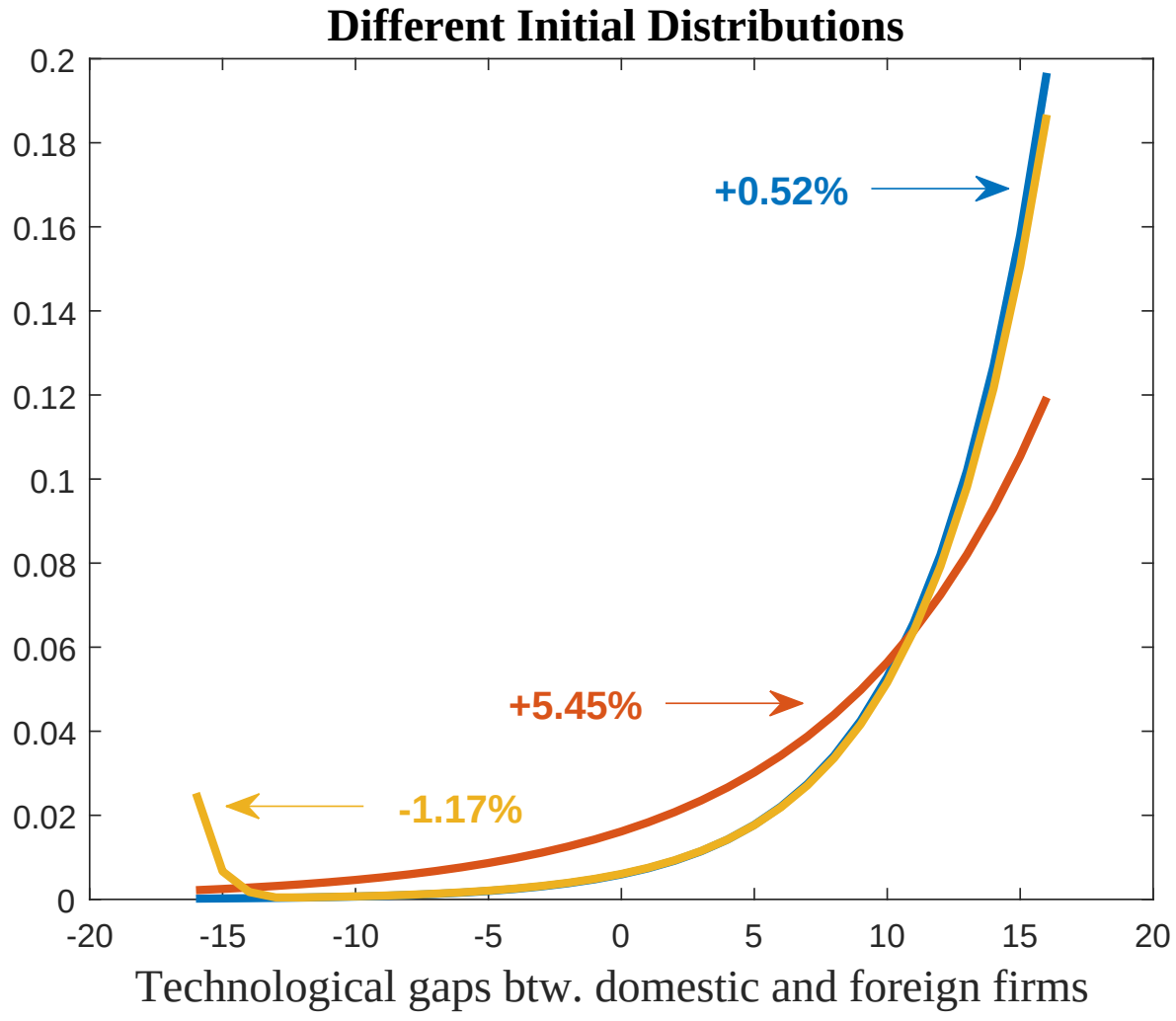


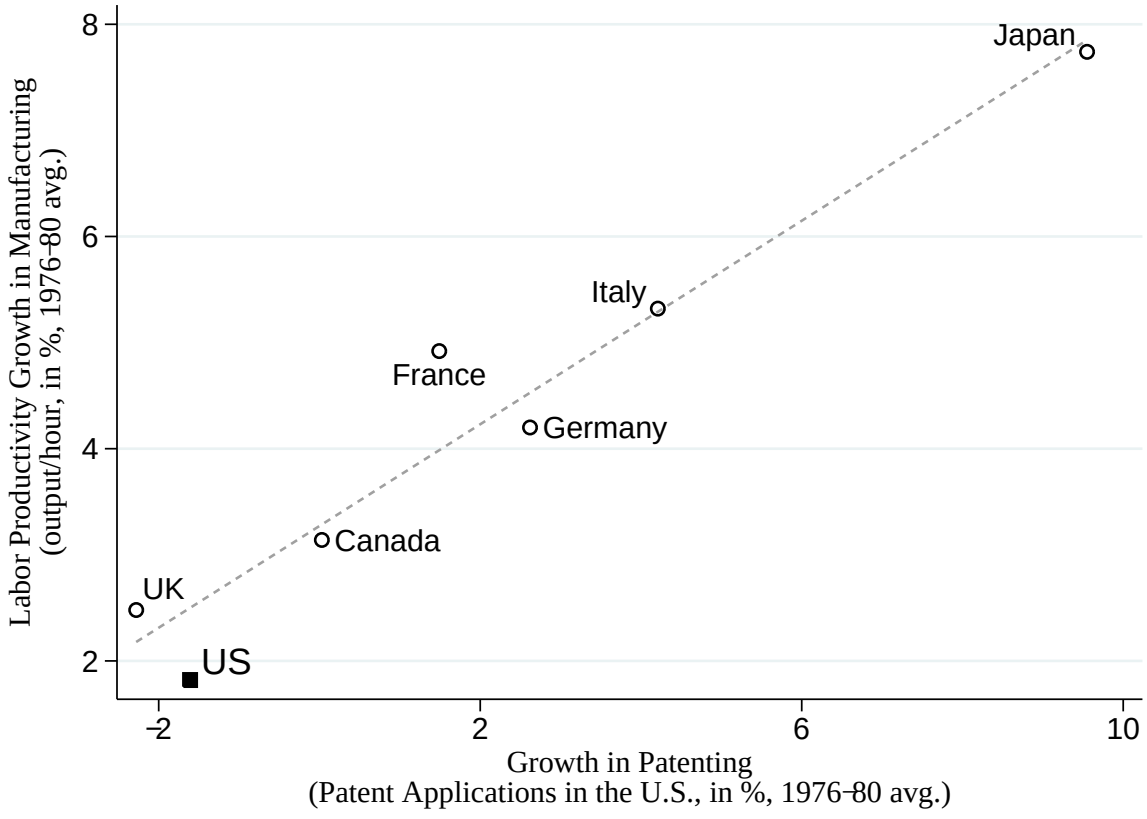
Even an advanced country can get hurt!

Conclusion

- Built a new DGE model with endogenous productivity growth, international trade and strategic interaction between competing firms.
- Strategic interaction (competition) channel is quantitatively very important.
- Policies have different implications in different horizons:
  - Protectionist response, short-run gains, long-run losses
  - R&D subsidy leads to notable welfare gains in longer horizons
- Governing globalization? Yes, but with innovation policy, not protectionism!
- Application: Lessons for Brexit?

APPENDIX

Another quote ...

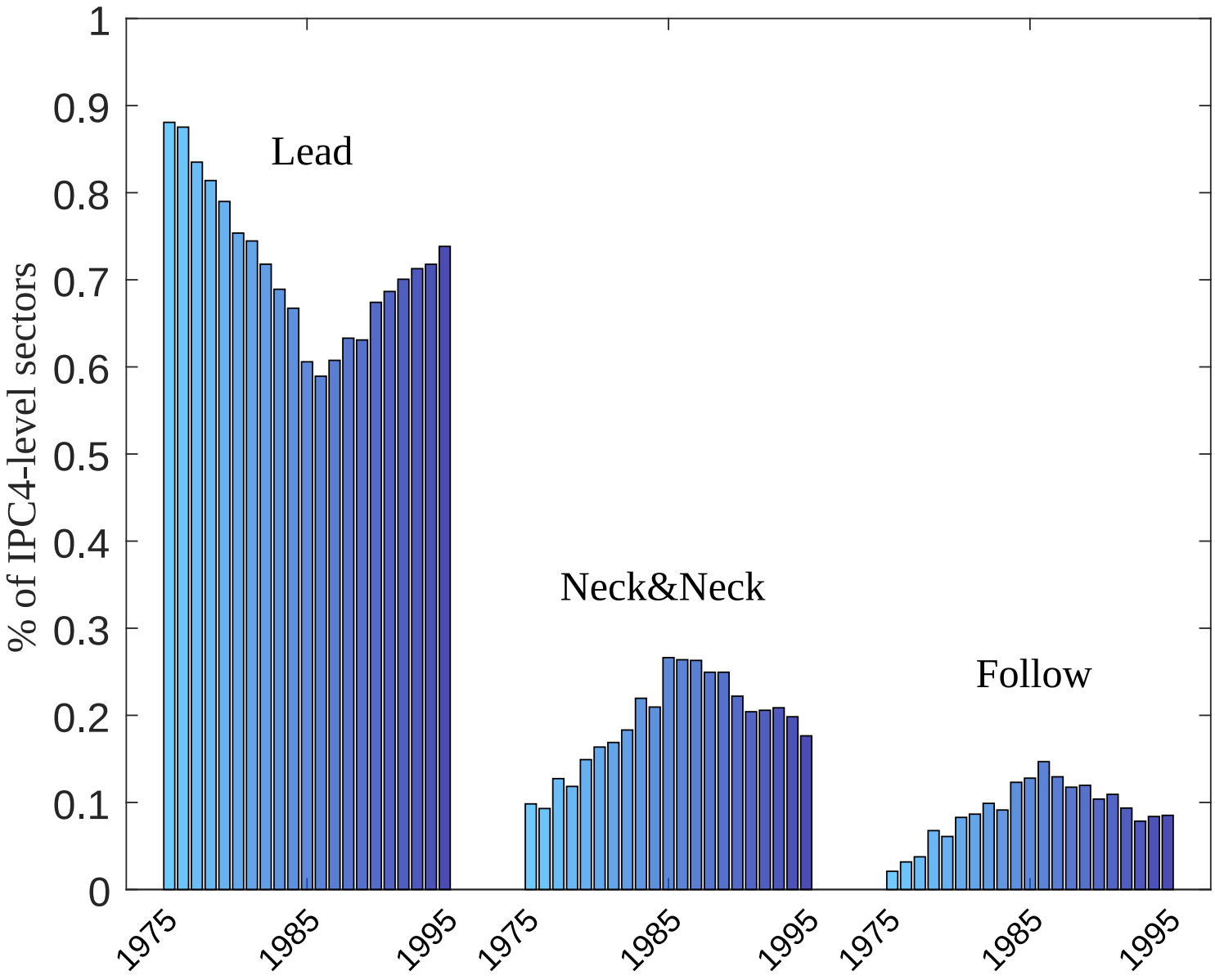


" ... these industries are dominated by a few nations and firms so that competitive advantage brings significant economic profits and political influence. Thus, if the United States becomes a net importer and a technically inferior producer, it would also become a less independent, less influential and less secure nation."

U.S. Council of National Security (1986)

back

Evolution of Technological Leadership Over Time



back

Technology

$$Y_{ct} = \frac{L_c^{\beta}}{1-\beta} \int_0^1 \left(q_{Ajt}^{\frac{\beta}{1-\beta}} k_{Ajt} + q_{Bjt}^{\frac{\beta}{1-\beta}} k_{Bjt} \right)^{1-\beta} dj. \tag{2}$$

back

Value Functions

Determinants of Innovation Decisions and Industrial Policy

$$
\begin{aligned}
& r_{US,t} V_{US,mt}(q_t) - \dot{V}_{US,mt}(q_t) \\
& \quad = \max_{x_{US,mt}} \Bigg\{ \Pi\left(m; \tau^{US}, \tau^{FN}\right) q_t - \left(1 - s^{US}\right) \alpha_{US} \frac{\left(x_{US,mt}\right)^{\gamma_{US}}}{\gamma_{US}} q_t \\
& \quad + x_{US,mt} \sum_{n_t=m+1}^{\bar{m}} \mathbb{F}_m(n_t) \left[V_{US,nt}\left(\lambda^{(n_t-m)} q_t\right) - V_{US,mt}(q_t) \right] \\
& \quad + \tilde{x}_{US,mt} \left[0 - V_{US,mt}(q_t) \right] \\
& \quad + \left(x_{FN(-m)t} + \tilde{x}_{FN(-m)t} \right) \sum_{n_t=-m+1}^{\bar{m}} \mathbb{F}_{-m}(n_t) \left[V_{US(-nt)}(q_t) - V_{US,mt}(q_t) \right] \Bigg\}
\end{aligned}
$$

$x_{US,mt}$: Domestic incumbent innovation

$\tilde{x}_{US,mt}$: Domestic entrant innovation

$x_{FN,mt}$: Foreign incumbent innovation

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back

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back

External Calibration

TABLE: Externally Calibrated Parameters

ψ	$\gamma, \tilde{\gamma}$	β	η	ρ	τ^{A}_{75-81}	τ^{B}_{75-81}	τ^{A}_{81-95}	τ^{B}_{81-95}
2	2	0.6	0.4	1%	5.3%	3.8%	19.2%	4.1%

- ψ: Utility parameter, standard macro value.
- $\gamma, \tilde{\gamma}$: Quadratic convex cost, large R&D literature (Akcigit and Kerr, 2017).
- β: Production function parameter, 70% labor share.
- η: Marginal cost of production, set $\eta = 1 - \beta$ for tractability.
- ρ: Standard discount rate, imply 2.8% interest rate in steady state.

back

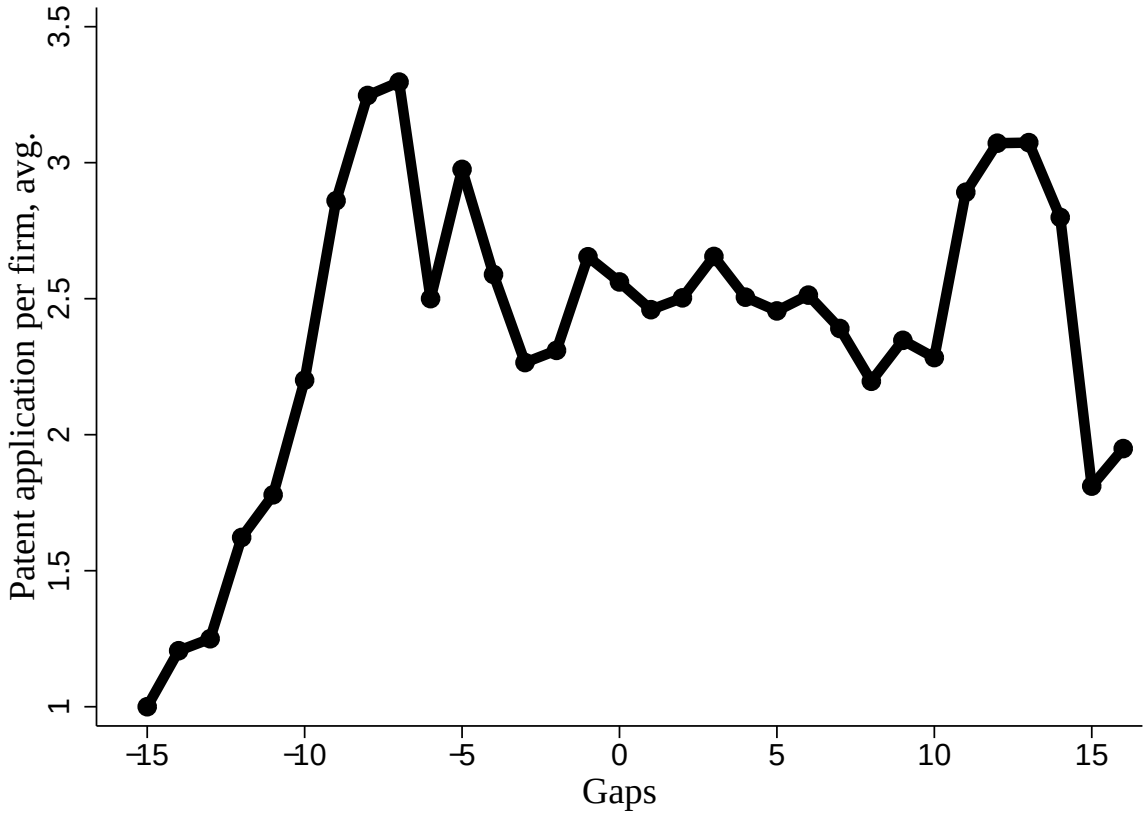
Internal Calibration

TABLE: Internally Calibrated Parameters

R&D scale		R&D scale		Step size	Iceberg	$\mathbb{F}(n)$
α_A	α_B	$\tilde{\alpha}_A$	$\tilde{\alpha}_B$	λ	κ	ϕ
0.69	1.14	44.6	8.77	1.49%	19.4%	1.35

back

Patenting Intensity - not smoothed



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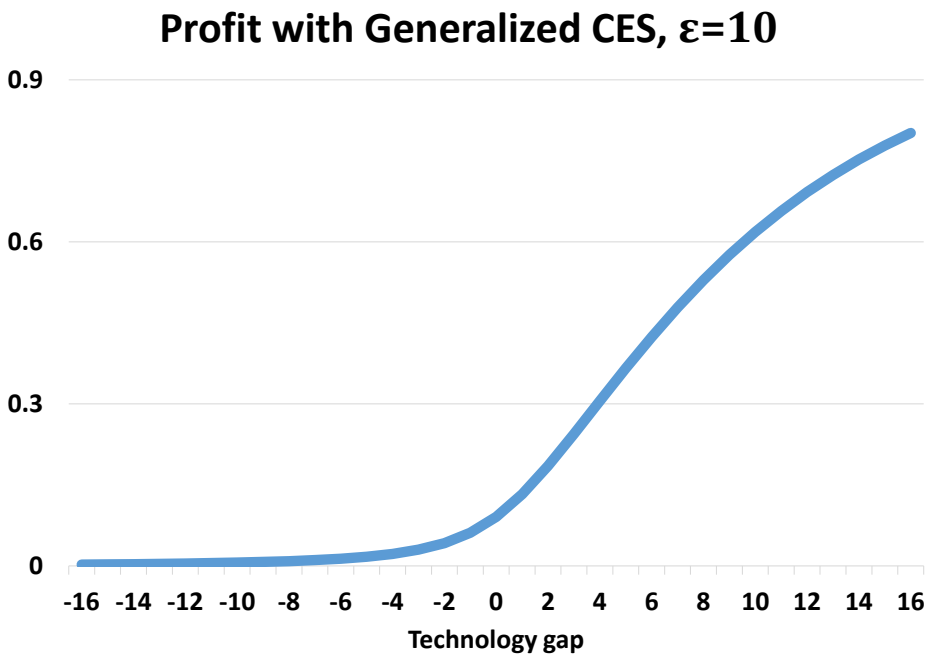
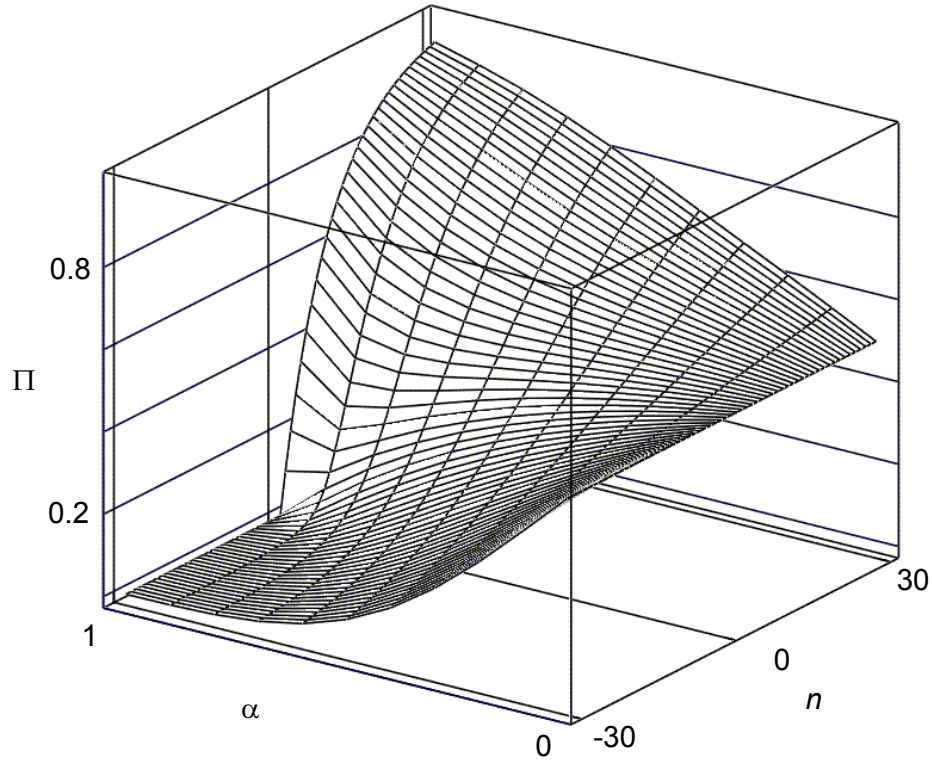
Generalized CES Production Function



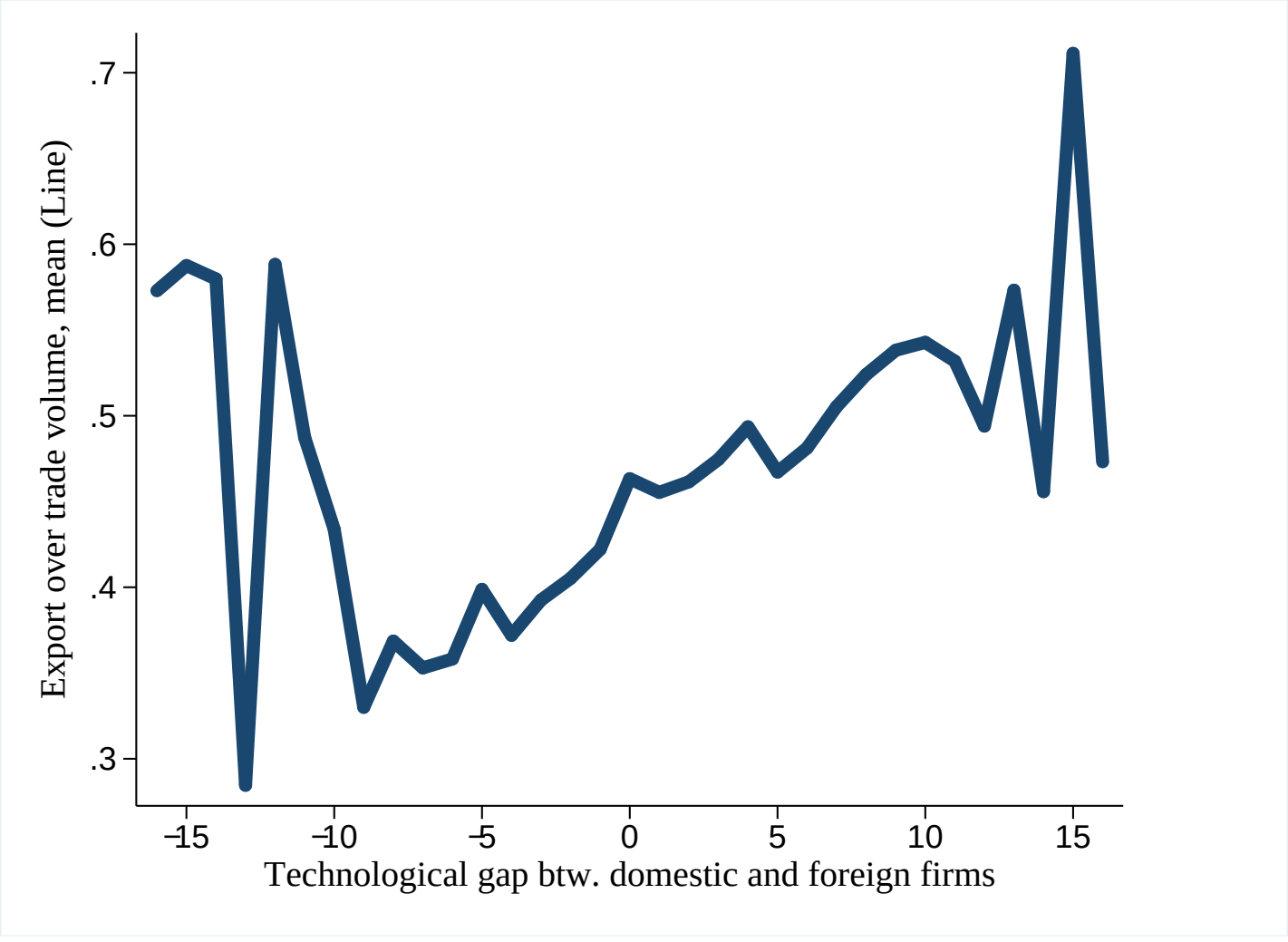


Profit

Aghion, Harris, Howitt, and Vickers (2001, *Restud*) study generalized CES.

back

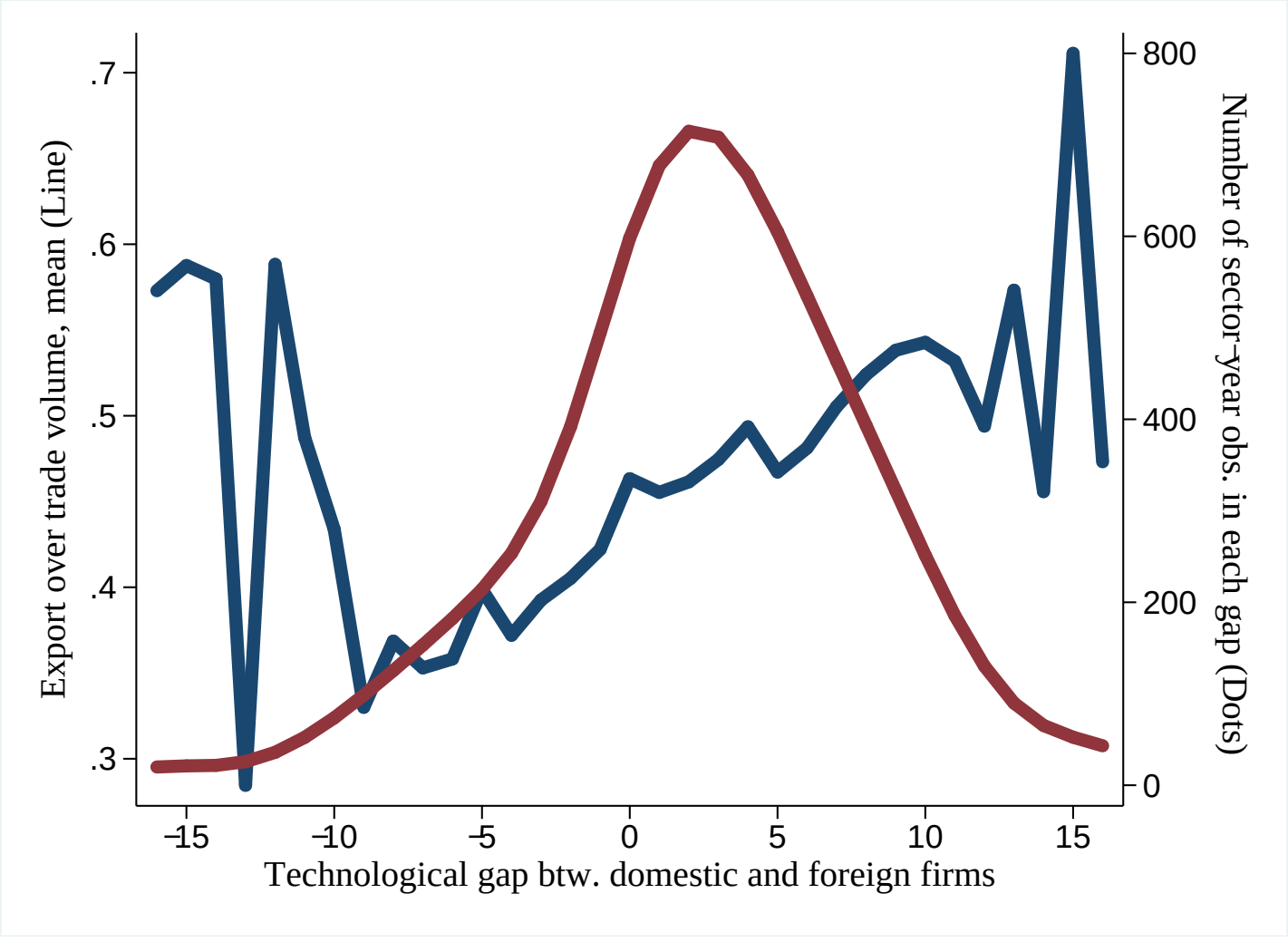
Validation IV: Technology Gaps and Trade



Data support the model prediction: higher exports in sectors with larger tech lead.

back

Validation IV: Technology Gaps and Trade



Data support the model prediction: higher exports in sectors with larger tech lead.

back

Validation IV: R&D Elasticity

- Exploit variation in R&D tax credit across states:

Dep. Var.:	$\ln(R\&D_t)$ (1)	$\ln(Patents_t)$ (2)
$\ln(State\ credit_t)$	3.153 (10.92)***	2.948 (10.93)***
Year dummy	Yes	Yes
Firm dummy	Yes	Yes

$$\ln Y_{jst} = const. + \ln SC_{st} + \psi_j + \psi_t + u_t$$

- Model counterpart of R&D elasticity:

$$\frac{d\log(\text{R\&D})}{d\log(Subsidy)} \approx 2.30$$

back

Policy Interaction

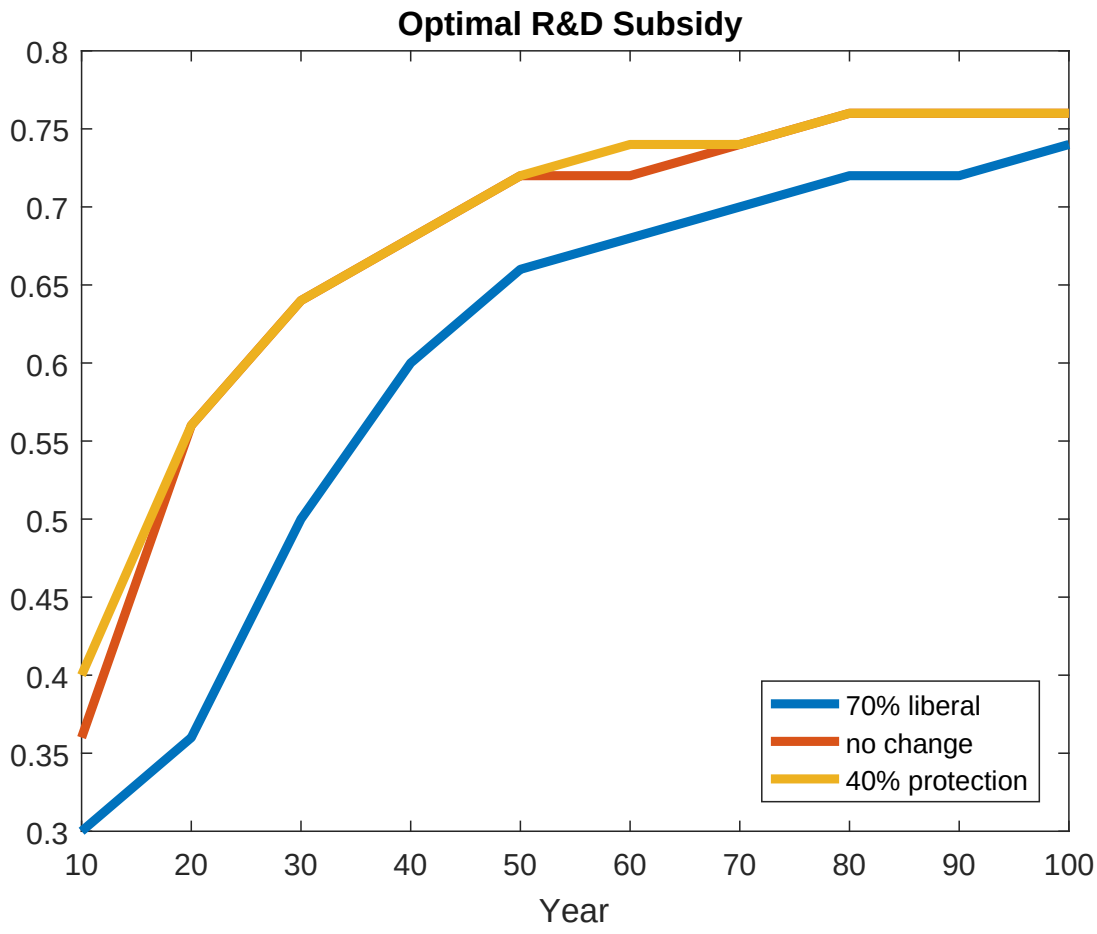


FIGURE: Optimal R&D policies for different tariff levels

back

Welfare Effects of Protectionist Policies on Foreign

Q1. What is the impact of a 20% increase in US tariffs on foreign welfare?

Welfare Effects of Protectionist Policies on Foreign

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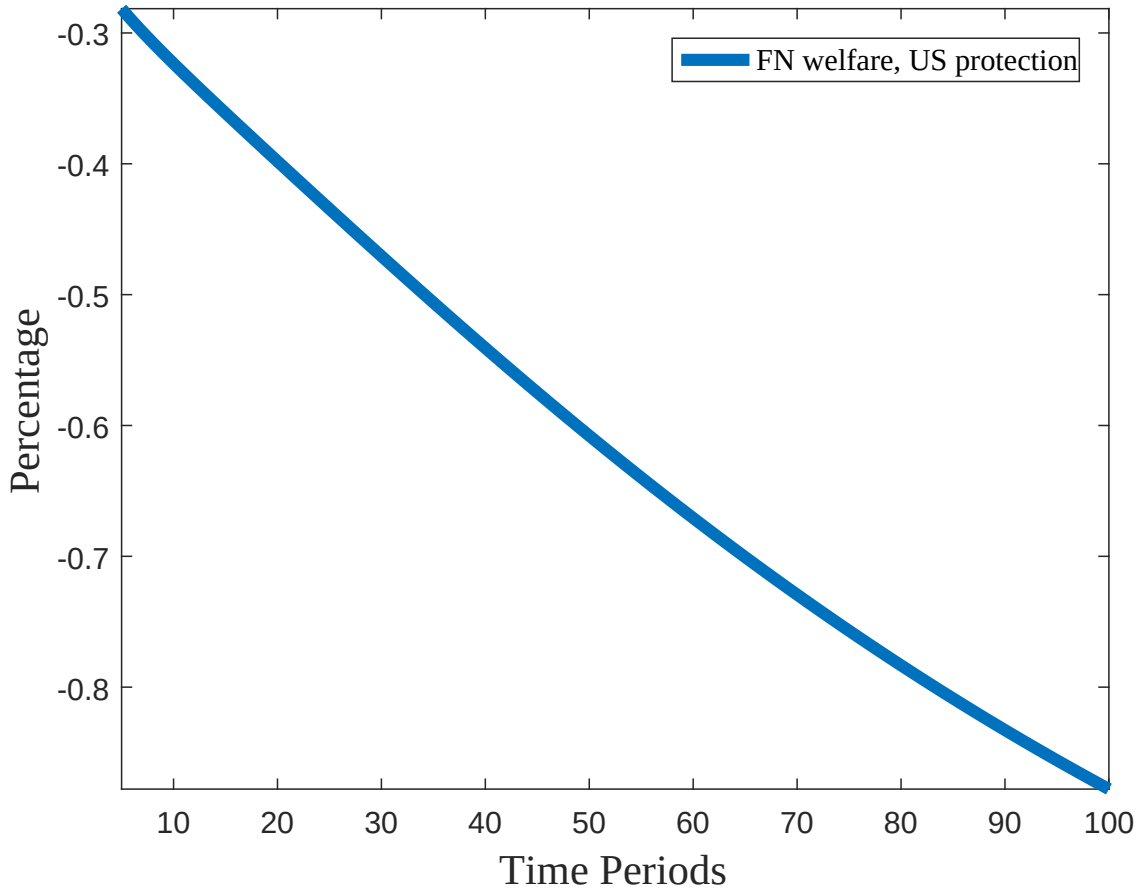


It is negative and deteriorates over time.

back

Welfare Effects of Protectionist Policies: Retaliation

Q1. How does optimal tariff respond when foreign country retaliate?

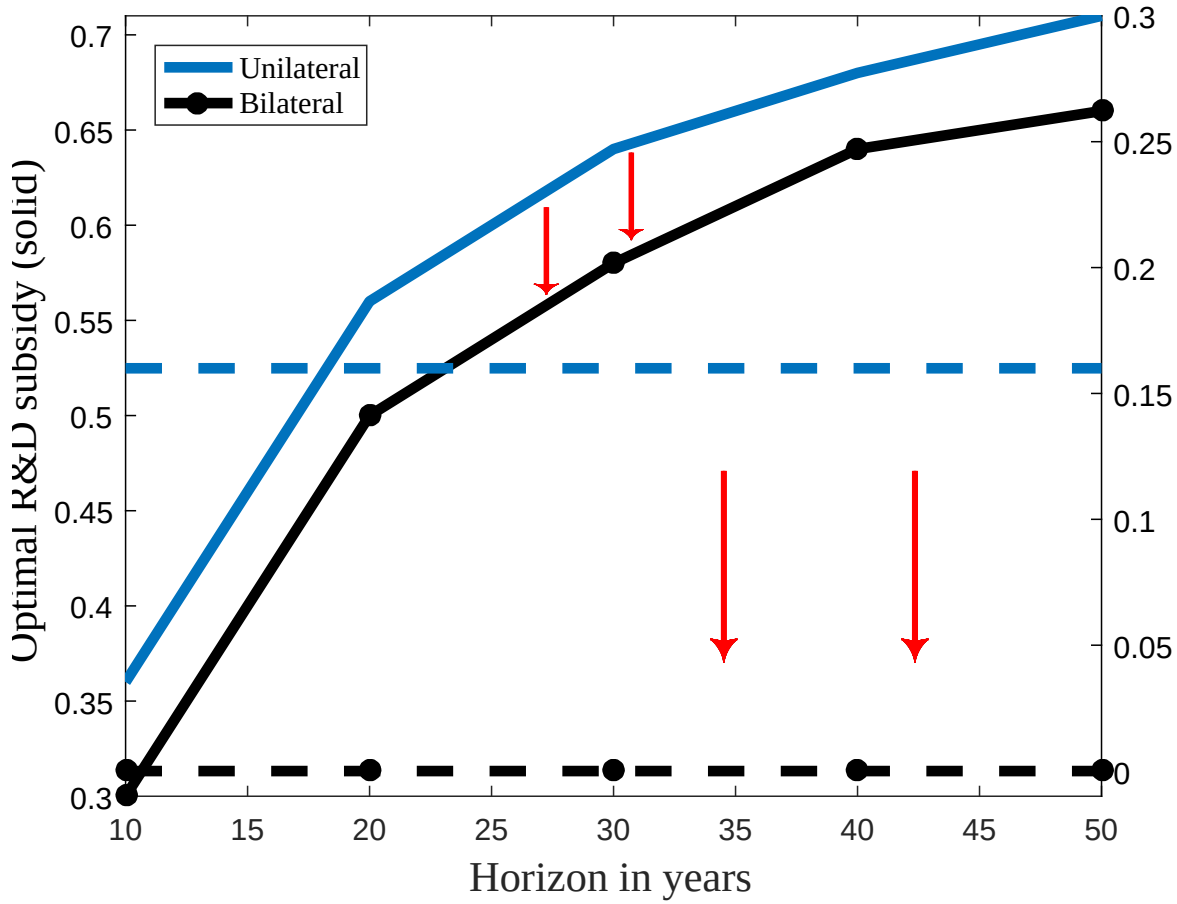
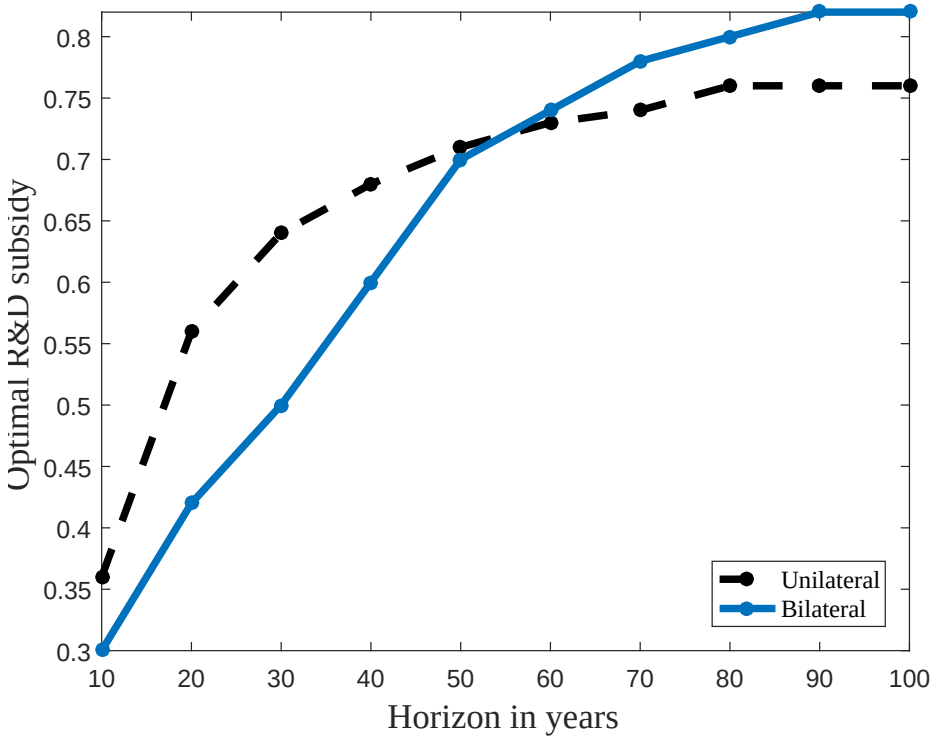


FIGURE: Optimal joint policy under retaliation

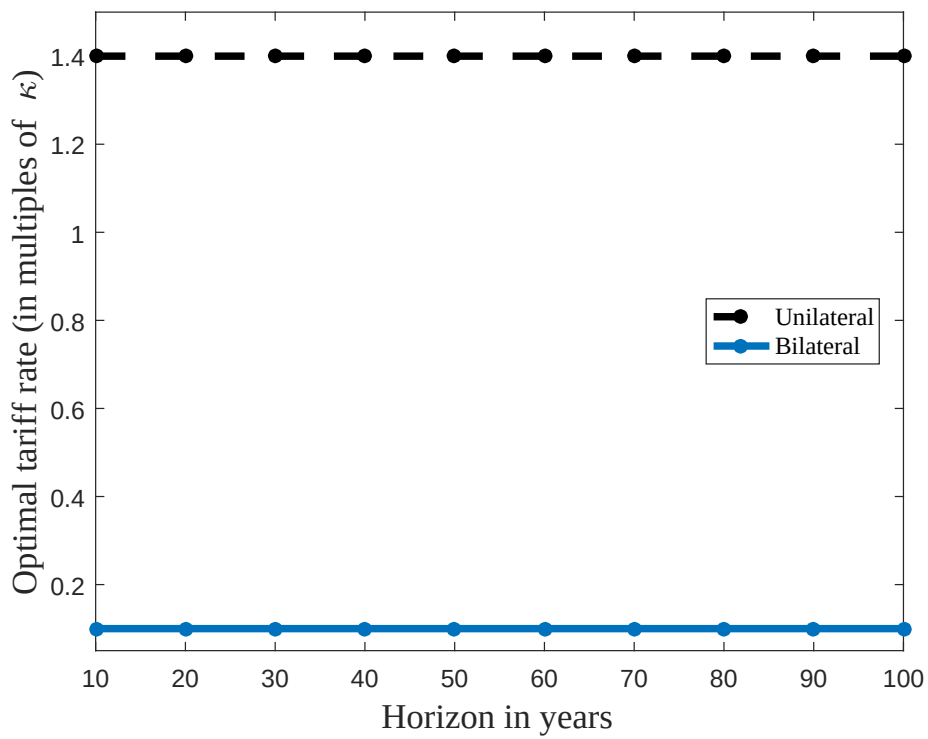
back

Optimal Joint Policy

- How does optimal tariff respond when foreign country retaliate?



A) Optimal innovation response to tariffs



B) Optimal tariff policy

FIGURE: Innovation response to tariffs and optimal tariff policy

back

Modeling Labor in the Intermediate Goods Sector

- Assume that intermediate goods are produced using labor:

$$k_{jt} = \frac{\bar{q}_{ct}}{\eta} l_{jt}.$$

- Profits from domestic sales and exports become

$$\pi\left(q_{jt}\right) = \left[\frac{1-\beta}{\eta}\frac{\bar{q}_{ct}}{w_{ct}}\right]^{\frac{1-\beta}{\beta}} \beta q_{jt} \quad \textit{and} \quad \pi^{*}\left(q_{jt}\right) = \left[\frac{1-\beta}{(1+\kappa)\,\eta}\frac{\bar{q}_{ct}}{w_{ct}}\right]^{\frac{1-\beta}{\beta}} \beta L_f q_{cjt}.$$

- Solving for the wage yields

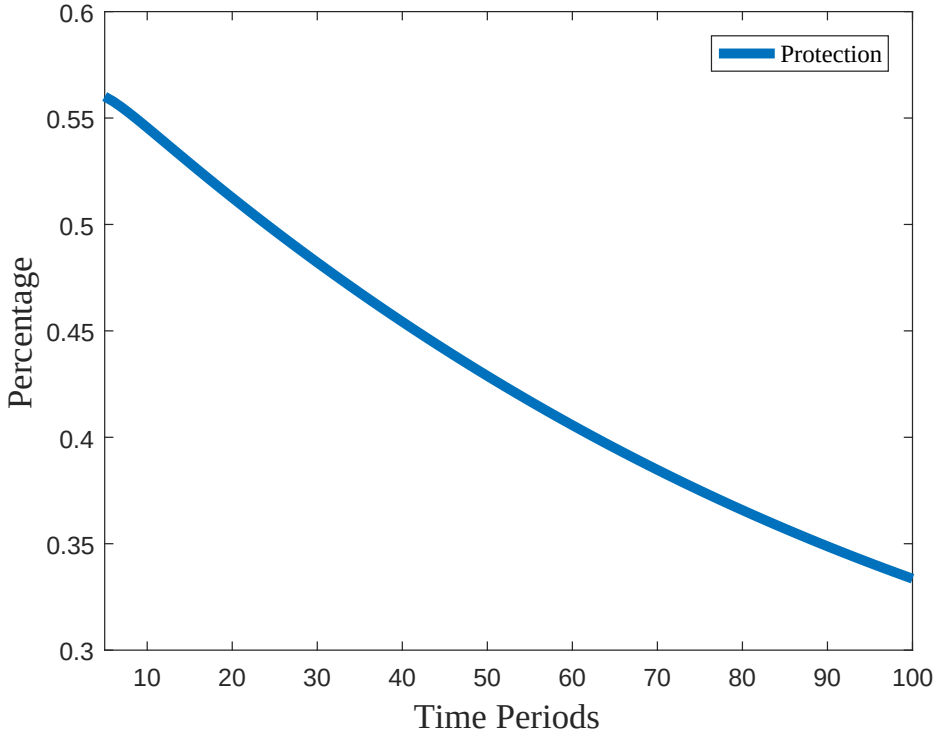
$$\frac{w_{ct}}{\bar{q}_{ct}} = \chi \bar{q}_{ct}^{-\beta} \left[\underbrace{Q_{ct}^{D} + Q_{ct}^{X} + (1+\kappa)^{\frac{\beta-1}{\beta}} Q_{ct}^{X}}_{\textit{denote } \bar{Q}_{ct}}\right]^{\beta} \equiv \chi \left[\frac{\bar{Q}_{ct}}{\bar{q}_{ct}}\right]^{\beta}.$$

- In the special case where $\bar{q}_{ct} = \bar{Q}_{ct}$ we have

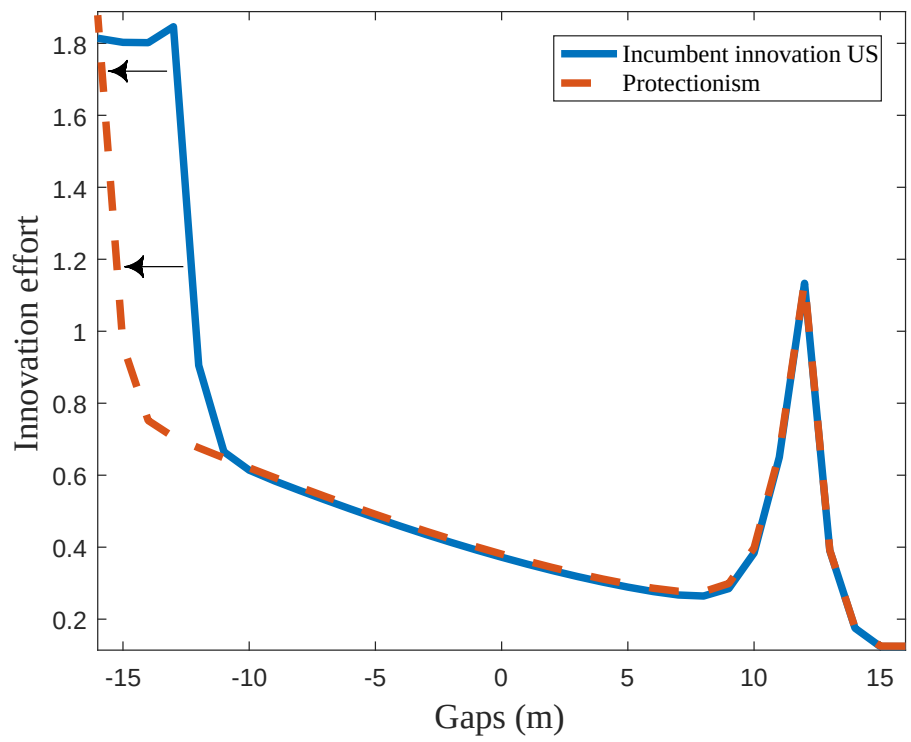
$$w_{ct} = \chi \bar{Q}_{ct}.$$

Welfare Effects of Protectionist Policies

1. What is the welfare effect of a 20% increase in tariffs?
2. What is the effect of a 20% increase on innovation?



A) Consumption equivalent welfare

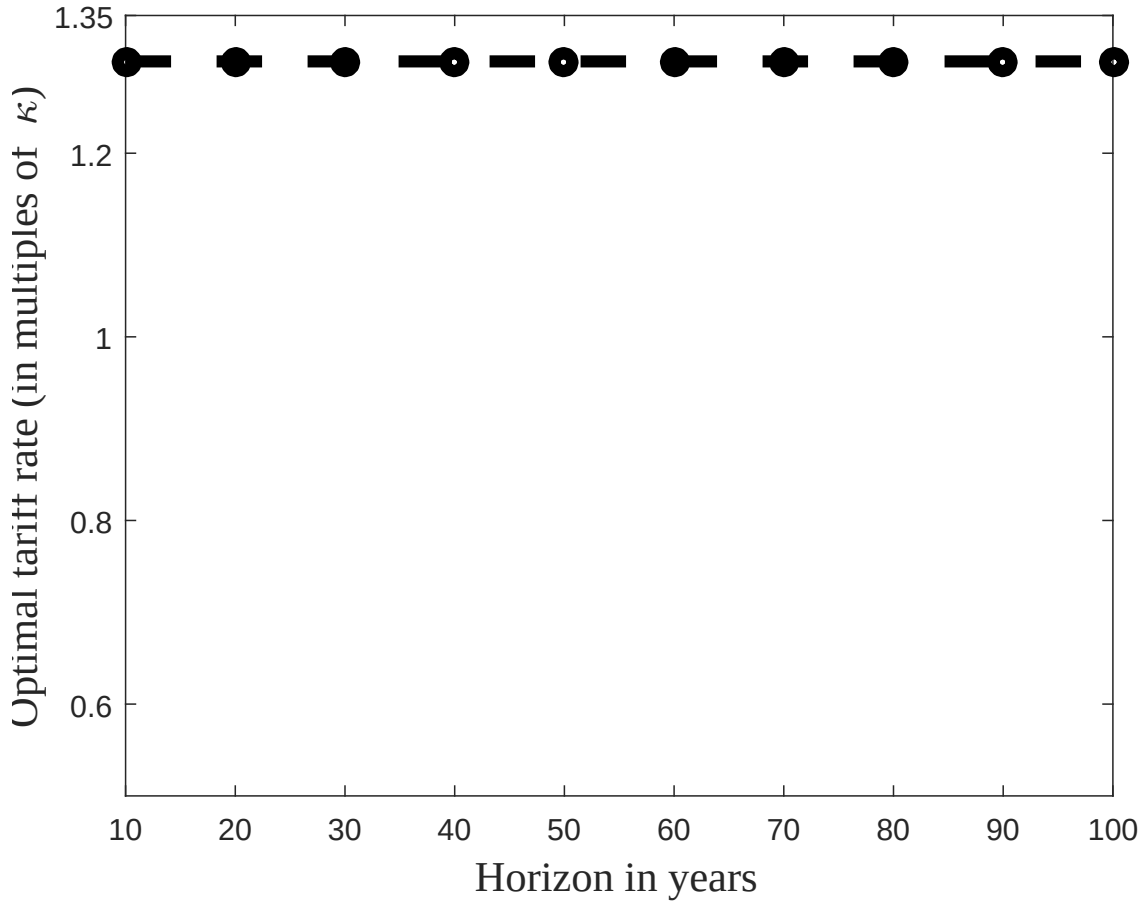


B) Innovation response of incumbents

FIGURE: Welfare effects of protectionism: unilateral 20% increase in trade barriers

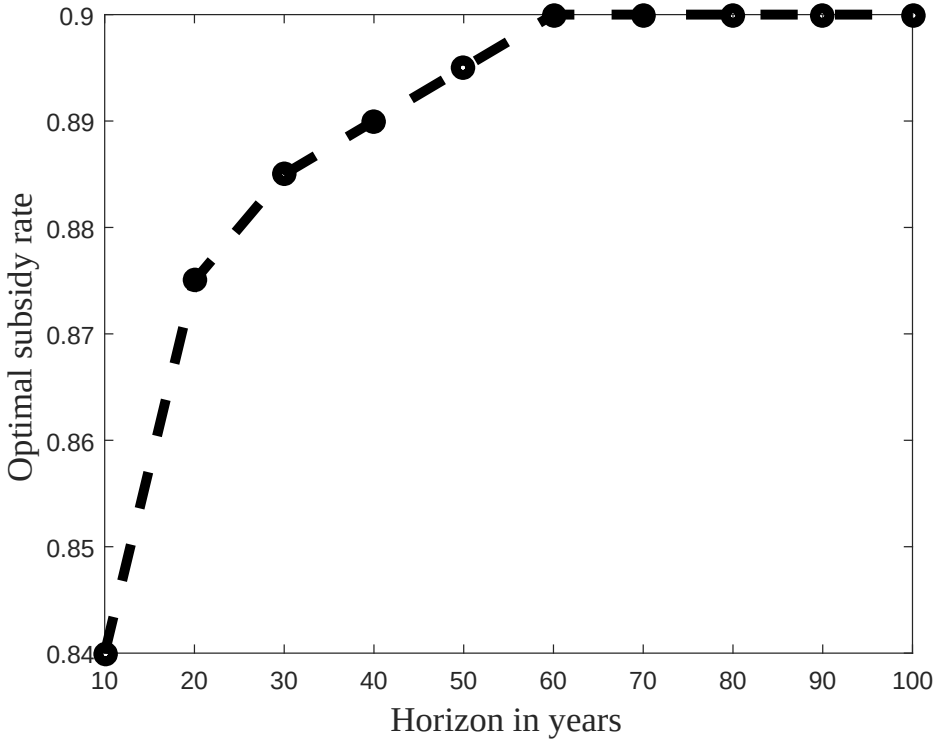
Welfare Effects of Protectionist Policies

1. How does innovation respond to an increase in the tariff rate?
2. What is the optimal tariff rate for different policy horizons?

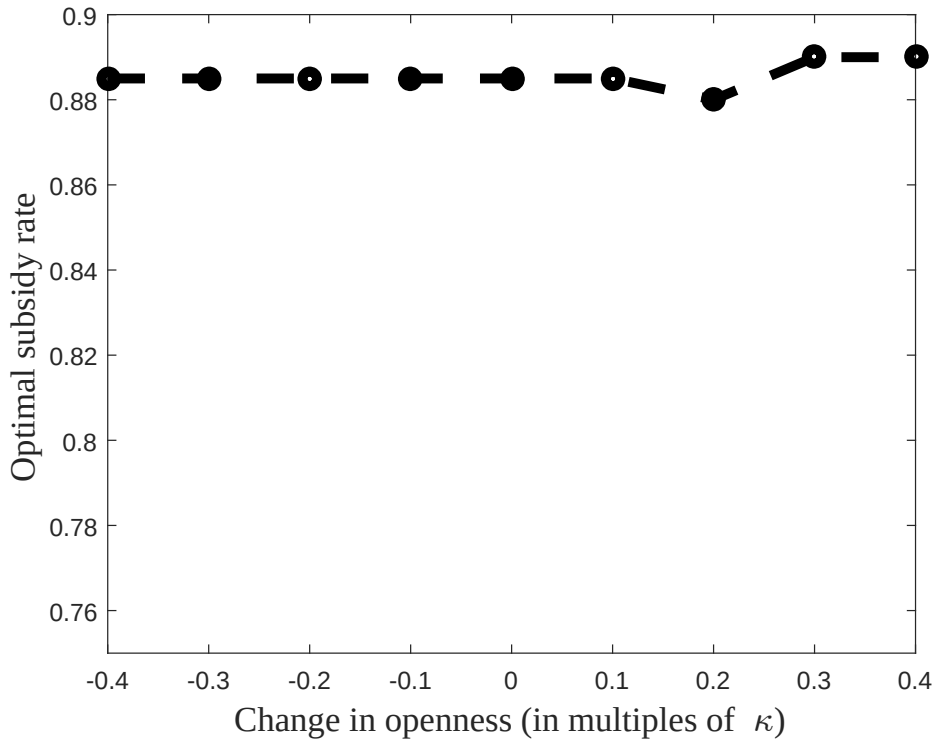


Optimal Subsidy Policy

1. What is the optimal subsidy rate for different time horizons?
2. How does it depend on openness?



A) Over different horizons

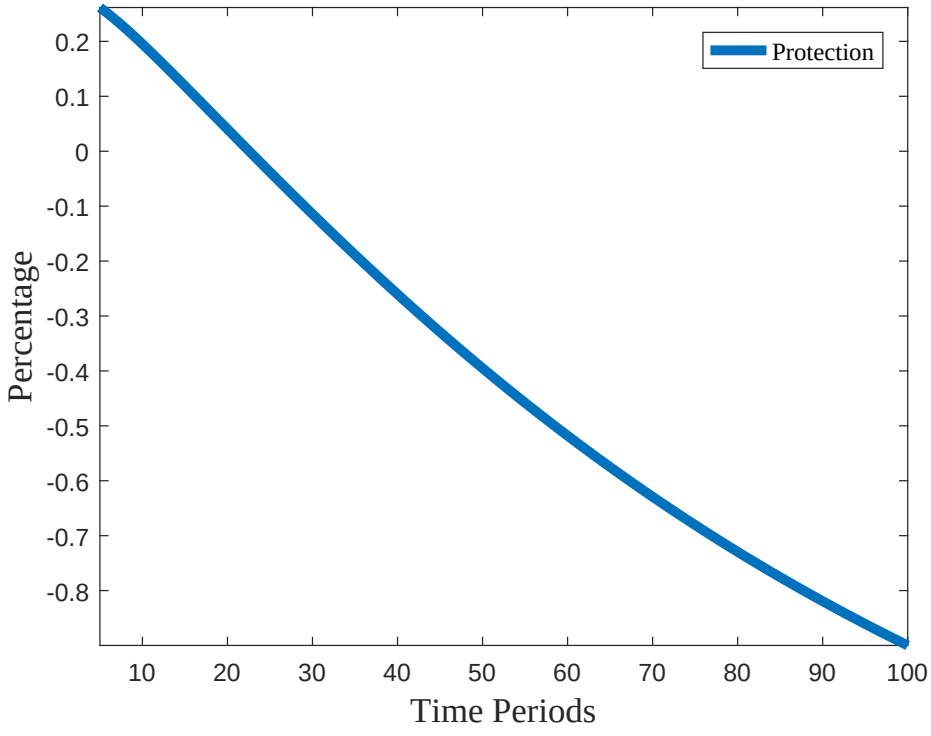


B) Over openness (fixed horizon of 35 years)

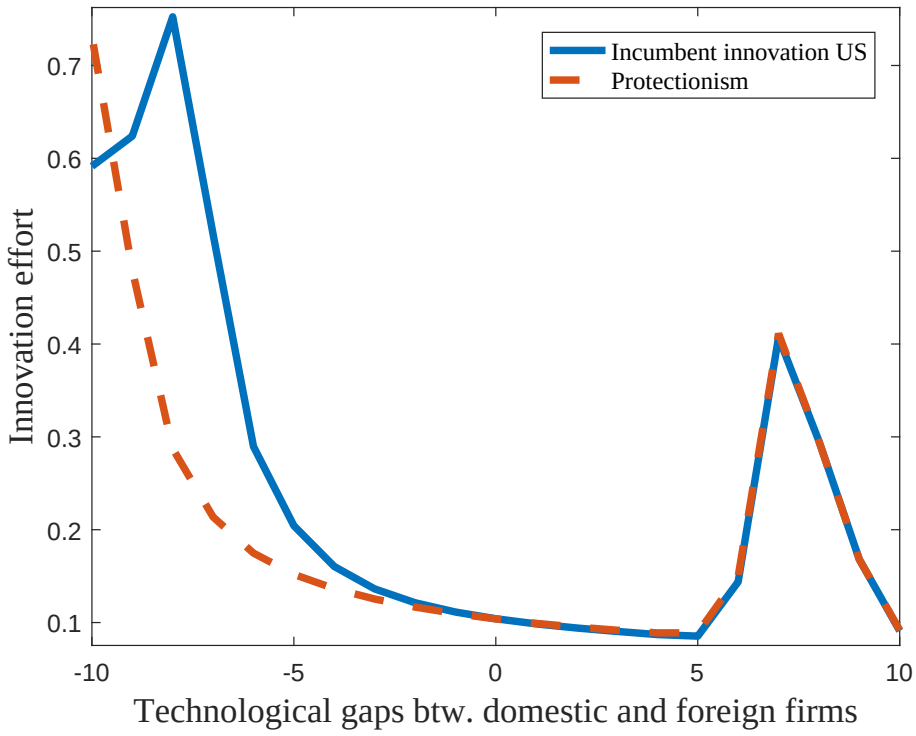
FIGURE: Optimal U.S. R&D subsidy, over different horizons and levels of openness

Welfare Effects of Protectionist Policies, with $\bar{m} = 10$

Q1. What is the impact of a 20% increase in tariffs on welfare and innovation?



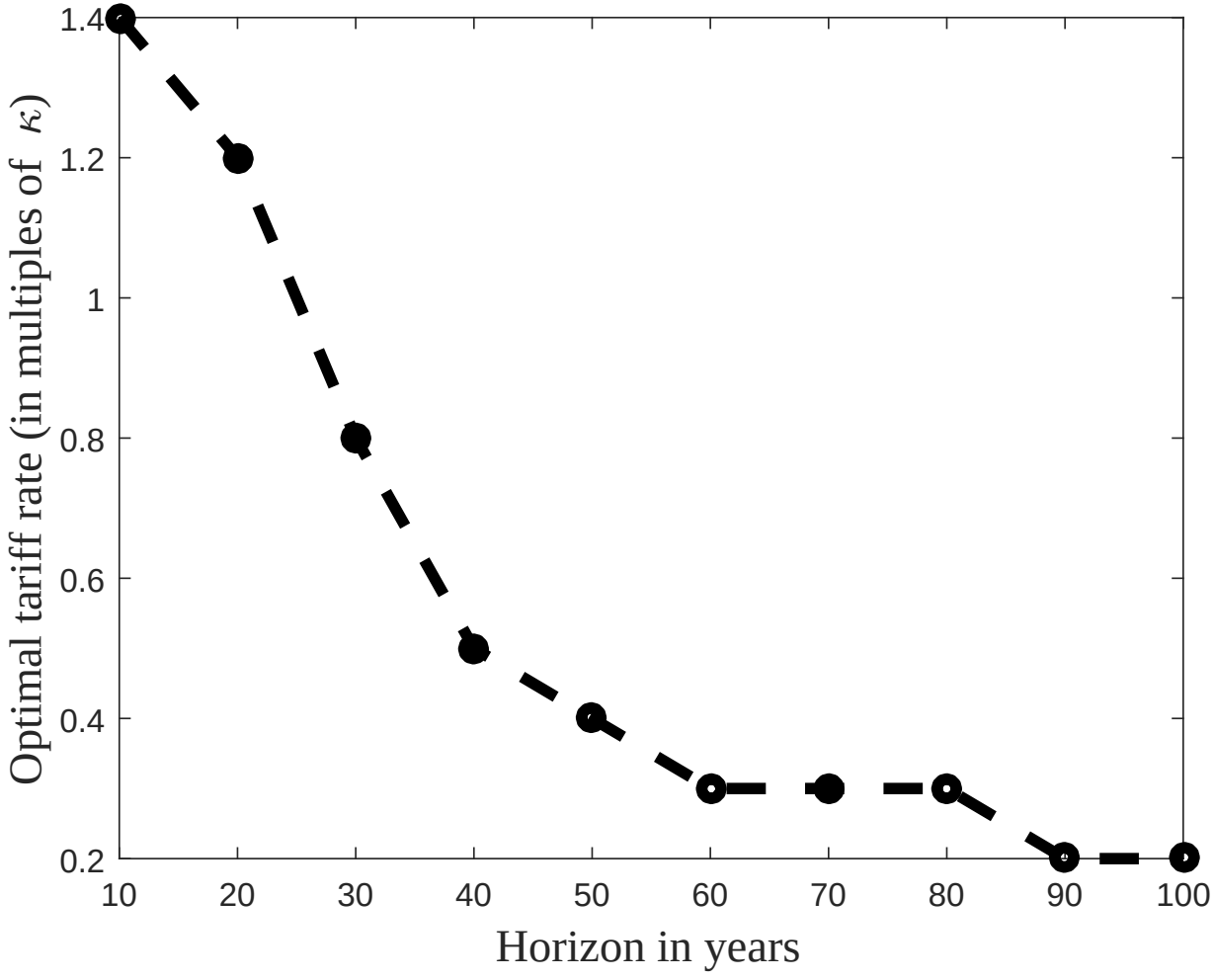
A) Consumption equivalent welfare



B) Innovation response of incumbents

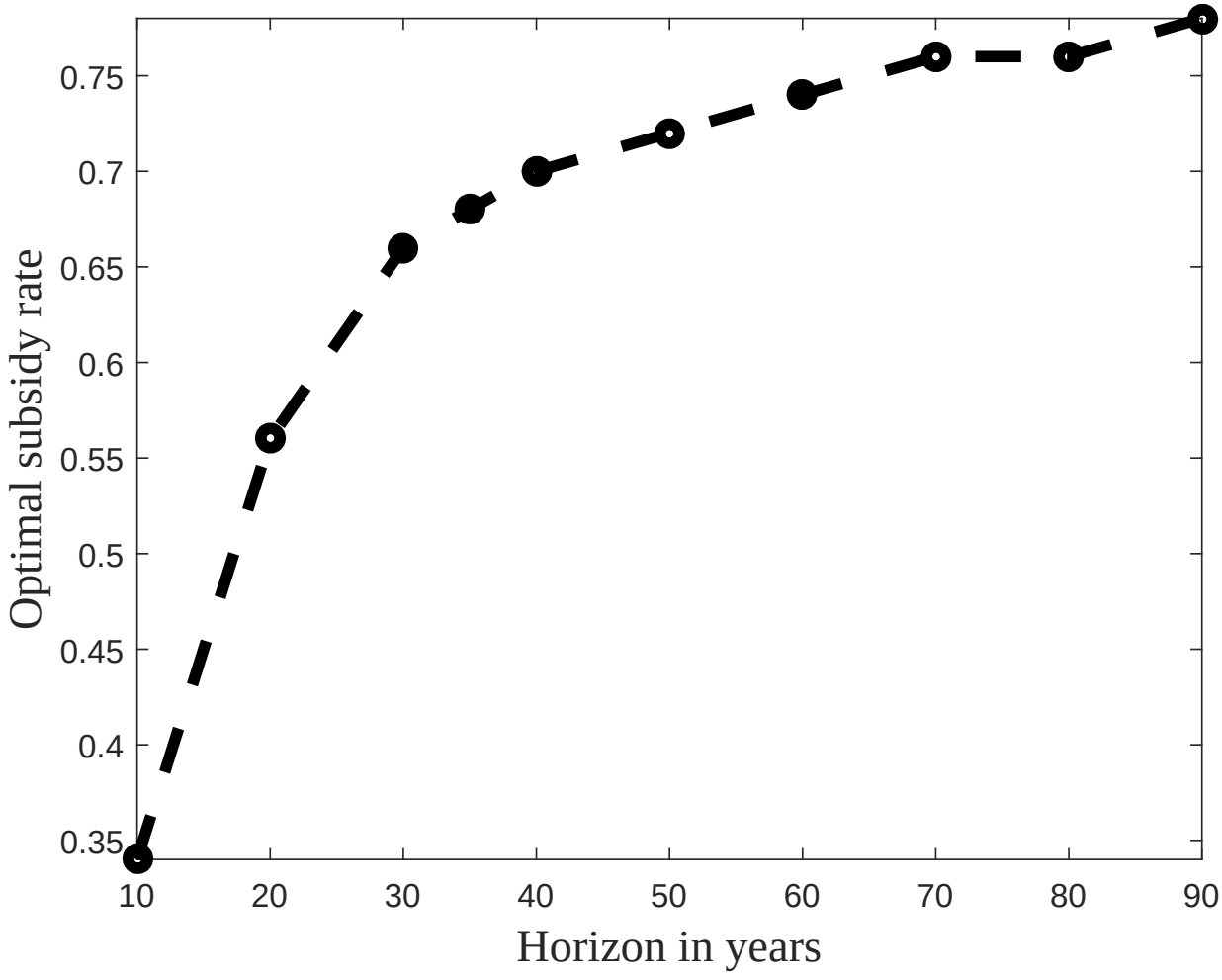
Welfare Effects of Protectionist Policies, with $\bar{m} = 10$

Q1. What is the optimal tariff rate for different policy horizons?



Optimal Subsidy Policy, with $\bar{m} = 10$

Q1. What is the optimal subsidy rate for different policy horizons?



Acemoglu, D., and U. Akcigit (2012): "Intellectual Property Rights Policy, Competition and Innovation," *Journal of the European Economic Association*, 10(1), 1–42.

Acemoglu, D., U. Akcigit, D. Hanley, and W. R. Kerr (2016): "Transition to Clean Technology," *Journal of Political Economy*, 124(1), 52–104.

Aghion, P., A. Bergeaud, M. Lequien, and M. Melitz (2017): "The Impact of Exports on Innovation: Theory and Evidence," Manuscript.

Aghion, P., N. Bloom, R. Blundell, R. Griffith, and P. Howitt (2005): "Competition and Innovation: An Inverted-U Relationship," *Quarterly Journal of Economics*, 120(2), 701–728.

Aghion, P., C. Harris, P. Howitt, and J. Vickers (2001): "Competition, Imitation and Growth with Step-by-step Innovation," *Review of Economic Studies*, 68(3), 467–492.

Aghion, P., C. Harris, and J. Vickers (1997): "Competition and Growth with Step-by-step Innovation: An Example," *European Economic Review*, 41(3), 771–782.

Akcigit, U., and W. R. Kerr (2017): "Growth through Heterogeneous Innovations," *Journal of Political Economy*.

Alessandria, G., and H. Choi (2014): "Do falling iceberg costs explain recent U.S. export growth?," *Journal of International Economics*, 94(2), 311–325.

Arkolakis, C., A. Costinot, and A. Rodríguez-Clare (2012): "New Trade Models, Same Old Gains?," *American Economic Review*, 102(1), 94–130.

Atkeson, A., and A. T. Burstein (2010): "Innovation, Firm Dynamics, and International Trade," *Journal of Political Economy*, 118(3), 433–484.

Autor, D., D. Dorn, G. H. Hanson, G. Pisano, and P. Shu (2016): "Foreign Competition and Domestic Innovation: Evidence from U.S. Patents," National Bureau of Economic Research # 22879.

Barattieri, A., M. Cacciatore, and F. Ghironi (2017): "Protectionism and the Business Cycle," Manuscript.

Bloom, N., M. Draca, and J. Van Reenen (2016): "Trade Induced Technical Change? The Impact of Chinese Imports on Innovation, IT and Productivity," *The Review of Economic Studies*, 83(1), 87.

Bloom, N., P. M. Romer, S. J. Terry, and J. Van Reenen (2013): "A Trapped-factors Model of Innovation," *American Economic Review, Papers and Proceedings*, 103(3), 208–213.

Bombardini, M., B. Li, and R. Wang (2017): "Import Competition and Innovation: Evidence from Chinese Patents," University of British Columbia Working Paper.

Broda, C., N. Limao, and D. E. Weinstein (2008): "Optimal Tariffs and Market Power: The Evidence," *American Economic Review*, 98(5), 2032–65.

Buera, F. J., and E. Oberfield (2016): "The Global Diffusion of Ideas," National Bureau of Economic Research # 21844.

Burstein, A., and M. J. Melitz (2013): "Trade Liberalization and Firm Dynamics," in *Advances in Economics and Econometrics Tenth World Congress. Applied Economics*, vol. 2, pp. 283–328.

Bustos, P. (2011): "Trade Liberalization, Exports, and Technology Upgrading: Evidence on the Impact of MERCOSUR on Argentinian Firms," *American Economic Review*, 101(1), 304–340.

Chen, C., and C. Steinwender (2016): "Import Competition, Heterogeneous Preferences of Managers and Productivity," Discussion paper.

Coelli, F., A. Moxnes, and K. H. Ulltveit-Moe (2016): "Better, Faster, Stronger: Global Innovation and Trade Liberalization," National Bureau of Economic Research WP 22647.

Costinot, A., D. Donaldson, J. Vogel, and I. Werning (2015): "Comparative Advantage and Optimal Trade Policy *," *The Quarterly Journal of Economics*, 130(2), 659.

Costinot, A., A. Rodríguez-Clare, and I. Werning (2016): "Micro to Macro: Optimal Trade Policy with Firm Heterogeneity," National Bureau of Economic Research # 21989.

Demidova, S., and A. Rodríguez-Clare (2009): "Trade Policy Under Firm-level Heterogeneity in a Small Economy," *Journal of International Economics*, 78(1), 100–112.

Eaton, J., and G. M. Grossman (1986): "Optimal Trade and Industrial Policy under Oligopoly," *Quarterly Journal of Economics*, 101(2), 383–406.

Fernandes, A. M. (2007): "Trade policy, trade volumes and plant-level productivity in Colombian manufacturing industries," *Journal of international economics*, 71(1), 52–71.

Gilbert, R. (2006): "Looking for Mr. Schumpeter: Where Are We in the Competition–Innovation Debate?," *Innovation policy and the economy*, 6, 159–215.

Gorodnichenko, Y., J. Svejnar, and K. Terrell (2010): "Globalization and innovation in emerging markets," *American Economic Journal: Macroeconomics*, 2(2), 194–226.

Grossman, G. M., and E. Helpman (1993): *Innovation and growth in the global economy*. MIT press.

Grossman, G. M., and E. L.-C. Lai (2004): "International Protection of Intellectual Property," *American Economic Review*, 94(5), 1635–1653.

Hashmi, A. R. (2013): "Competition and innovation: The inverted-U relationship revisited," *Review of Economics and Statistics*, 95(5), 1653–1668.

Hombert, J., and A. Matray (2015): "Can Innovation Help US Manufacturing Firms Escape Import Competition from China?," Discussion paper, CEPR Discussion Papers Nr 10666.

Iacovone, L. (2012): "The better you are the stronger it makes you: Evidence on the asymmetric impact of liberalization," *Journal of Development Economics*, 99(2), 474–485.

Iacovone, L., W. Keller, and F. Rauch (2011): "Innovation Responses to Import Competition," mimeo, Princeton University, March.

Impullitti, G. (2010): "International Competition and US R&D Subsidies: A Quantitative Welfare Analysis," *International Economic Review*, 51(4), 1127–1158.

Impullitti, G., and O. Licandro (2017): "Trade, Firm Selection, and Innovation: The Competition Channel," *Economic Journal*.

Ossa, R. (2015): "A Quantitative Analysis of Subsidy Competition in the US," National Bureau of Economic Research Working Paper # 20975.

Perla, J., C. Tonetti, and M. E. Waugh (2015): "Equilibrium Technology Diffusion, Trade, and Growth," National Bureau of Economic Research Working Paper # 20881.

Rivera-Batiz, L. A., and P. M. Romer (1991): "Economic Integration and Endogenous Growth," *The Quarterly Journal of Economics*, 106(2), 531–555.

Rodrik, D. (2004): "Industrial Policy for the Twenty-first Century," CEPR Discussion Paper #4767.

Sampson, T. (2016): "Dynamic Selection: An Idea Flows Theory of Entry, Trade, and Growth," *The Quarterly Journal of Economics*, 131(1), 315–380.

Spencer, B. J., and J. A. Brander (1983): "International R&D Rivalry and Industrial Strategy," *Review of Economic Studies*, 50(4), 707–722.