Heterogeneous Innovations and Growth under Imperfect Technology Spillovers

Karam Jo
(KDI)

Seula Kim
(Penn State, IZA)

Frontier Topics in Macro-Finance Conference

May 2, 2025

Motivation

- **Firm innovations manifest in diverse forms with different features**:
  - Firm innovation involves learning about existing technologies (Lucas and Moll 2014) + improving them
  - Some build on own existing technologies vs. others require learning new ones
  - Heterogeneous innovations impact firm performance and economic growth differently & firms pursue them for different purposes (Gilbert 2006; Akcigit and Kerr 2018; Garcia-Macia et al. 2019; Peters 2020; Argente et al. 2024)

Motivation

- **Firm innovations manifest in diverse forms with different features**:
  - Firm innovation involves learning about existing technologies (Lucas and Moll 2014) + improving them
  - Some build on own existing technologies vs. others require learning new ones
  - Heterogeneous innovations impact firm performance and economic growth differently & firms pursue them for different purposes (Gilbert 2006; Akcigit and Kerr 2018; Garcia-Macia et al. 2019; Peters 2020; Argente et al. 2024)
- **Limited studies on how learning shapes firm innovation incentives and decisions**:
  - Learning frictions can create strategic incentives for firms to pursue different innovations
  - Can lead to composition changes of innovations and different aggregate implications

Research Questions

★ **This Paper:** investigates the following questions both theoretically and empirically

Q. How do firms use different innovations when learning others' technology takes time?

Q. How does this process offer new insights into the aggregate implications of firm innovation, particularly in the context of increasing competition?

This Paper

- **Theory:**
  - Endogenous growth model (Ackigit and Kerr 2018, Peters 2020) + Imperfect technology spillover

This Paper

- **Theory:**
  - Endogenous growth model (Ackigit and Kerr 2018, Peters 2020) + Imperfect technology spillover
  - **Key features**: firms grow through two types of innovation s.t. friction

This Paper

- **Theory:**
  - Endogenous growth model (Ackigit and Kerr 2018, Peters 2020) + Imperfect technology spillover
  - **Key features**: firms grow through two types of innovation s.t. friction
    - Own-innovation vs Creative destruction: improves own product (or process) vs enter into new markets

This Paper

- **Theory:**
  - Endogenous growth model (Ackigit and Kerr 2018, Peters 2020) + Imperfect technology spillover
  - **Key features**: firms grow through two types of innovation s.t. friction
    - Own-innovation vs Creative destruction: improves own product (or process) vs enter into new markets
    - Imperfect technology spillover: takes time to learn others' technology

This Paper

- **Theory:**
  - Endogenous growth model (Ackigit and Kerr 2018, Peters 2020) + Imperfect technology spillover
  - **Key features**: firms grow through two types of innovation s.t. friction
    - Own-innovation vs Creative destruction: improves own product (or process) vs enter into new markets
    - Imperfect technology spillover: takes time to learn others' technology
  - **Key distinction**: Multi-product firms can build technological barriers to defend
    - ⁎ First model of multi-product firms using innovation strategically and making feedback effects

This Paper

- **Theory:**
  - Endogenous growth model (Ackigit and Kerr 2018, Peters 2020) + Imperfect technology spillover
  - **Key features**: firms grow through two types of innovation s.t. friction
    - Own-innovation vs Creative destruction: improves own product (or process) vs enter into new markets
    - Imperfect technology spillover: takes time to learn others' technology
  - **Key distinction**: Multi-product firms can build technological barriers to defend
    - First model of multi-product firms using innovation strategically and making feedback effects
- **Empiric:**
  - Firm-level data from the US Census Bureau integ. w/ USPTO patent db.
  - Own-innovation vs. Creative destruction using self-citation ratio
  - China's WTO accession as an exogenous competition shock (Pierce and Schott 2016, Handley and Limão 2017)

Related Literature and Contribution

- **Heterogeneity in innovation:** Aghion et al. 2004; Klette and Kortum 2004; Atkeson and Burstein 2010; Bernard et al. 2010; Dhingra 2013; Akcigit et al. 2018; Akcigit and Kerr 2018; Garcia-Macia et al. 2019; Atkeson and Burstein 2019; Peters 2020; Argente et al. 2024

- **Technology gap and spillovers:** Aghion et al. 2001, 2005; Dinopoulos and Syropoulos 2007; Aghion and Griffith 2008; Acemoglu and Akcigit 2012; Aghion et al. 2014; Andrews et al. 2016; Akcigit et al. 2018; Bessen et al., 2020; Akcigit and Ates 2021, 2023; Arora et al. 2021

- **Competition and innovation:** Aghion et al. 2001, 2004, 2005, 2009; Bloom et al. 2013, 2016, 2021; Dhingra 2013; Akcigit et al., 2018; Aghion et al. 2018; Hombert and Matray 2018; Shu and Steinwender 2019; Autor et al. 2020; Medina 2022; Helpman 2023

Related Literature and Contribution

- **Heterogeneity in innovation:** Aghion et al. 2004; Klette and Kortum 2004; Atkeson and Burstein 2010; Bernard et al. 2010; Dhingra 2013; Akcigit et al. 2018; Akcigit and Kerr 2018; Garcia-Macia et al. 2019; Atkeson and Burstein 2019; Peters 2020; Argente et al. 2024

⇒ ★ A rich endogenous growth model incorporating strategic interactions among different types of innovation and feedback effects on others' innovation and entry decisions

- **Technology gap and Spillovers:** Aghion et al. 2001, 2005; Dinopoulos and Syropoulos 2007; Aghion and Griffith 2008; Acemoglu and Akcigit 2012; Aghion et al. 2014; Andrews et al. 2016; Akcigit et al. 2018; Bessen et al., 2020; Akcigit and Ates 2021, 2023; Arora et al. 2021

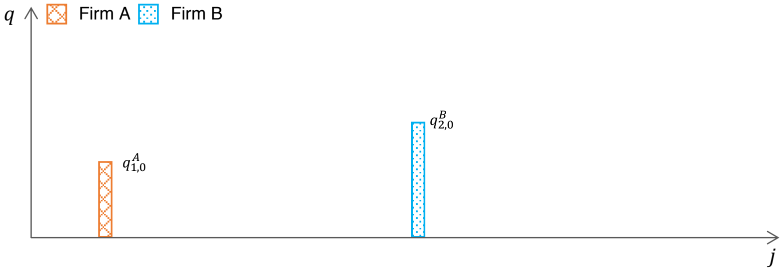
⇒ ★ Uncover an underlying endogenous force and mechanism behind the decreasing technology diffusion as a consequence of the strategic innovation choice of firms under learning frictions

- **Competition and innovation:** Aghion et al. 2001, 2004, 2005, 2009; Bloom et al. 2013, 2016, 2021; Dhingra 2013; Akcigit et al., 2018; Aghion et al. 2018; Hombert and Matray 2018; Shu and Steinwender 2019; Autor et al. 2020; Medina 2022; Helpman 2023

⇒ ★ A rich model of multi-product firms choosing heterogeneous innovations, enabling to assess the aggregate implications through innovation composition and reconcile the prior results

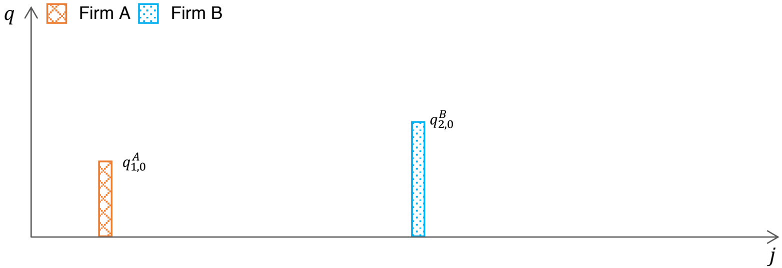
Table of Contents

Two-Firm Two-Product Innovation Example



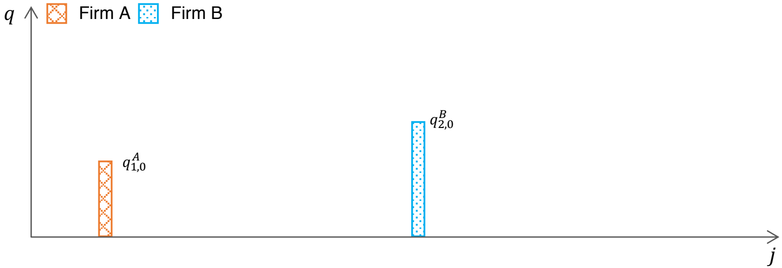
- Firm A owns product 1, firm B owns product 2
- Height of bar: product quality (technology) q (logged)
- Successful innovation improves product quality q (realized next period)
- Firms do two types of innovation: Own-innovation/Creative destruction

Own-Innovation (period 0)



- We are in period 0
- First, consider own-innovation only

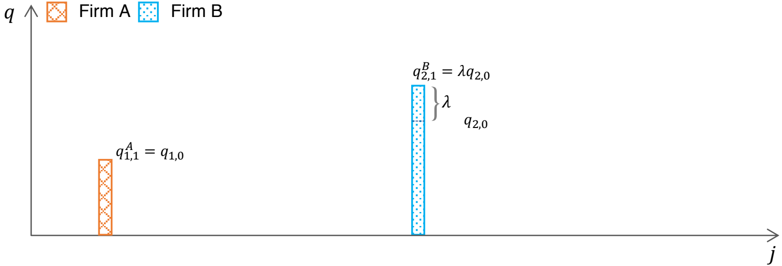
Own-Innovation (period 0)



- R&D investment ($R^{in}_{j,0}$) required but only a few can succeed
- Higher R&D investment $\Rightarrow$ higher success probability of innov. ($z_{j,0}$)
- Successful own-innovation improves $q_{j,0}$ by $\lambda > 1$

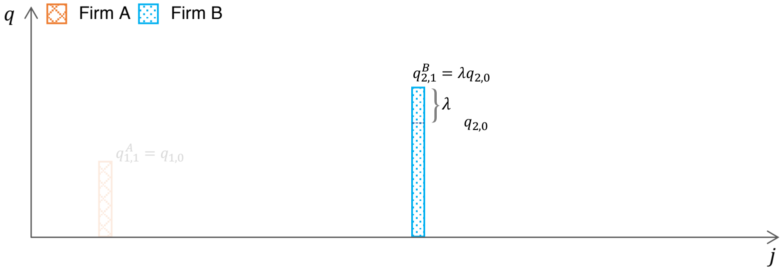
$$q_{j,1} = \begin{cases} q_{j,0} & \text{w/ prob. } 1 - z_{j,0} \\ \lambda q_{j,0} & \text{w/ prob. } z_{j,0} \end{cases}$$

Own-Innovation (period 1)



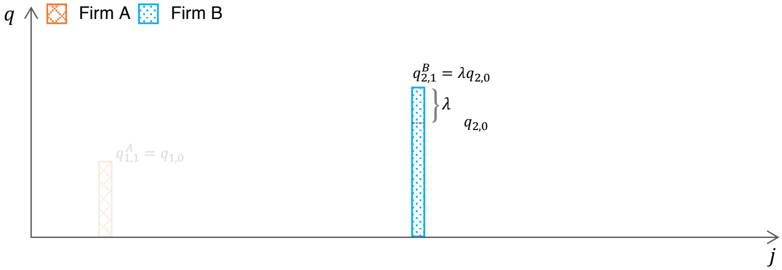
- We are in period 1 now
- Assume firm A fails while firm B succeeds in own-innovation

Creative Destruction (period 1)



- Now, let's allow creative destruction

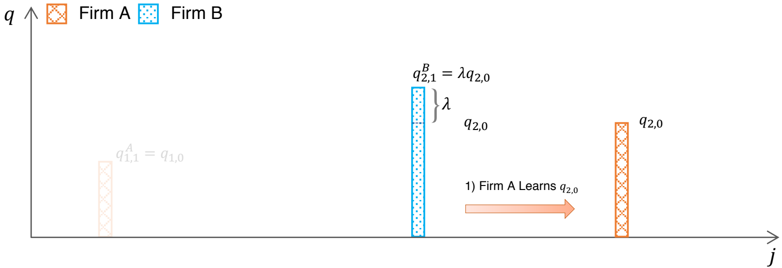
Creative Destruction (period 1)



- Now, let's allow creative destruction
- Firm A wants to take over prod. mkt. 2 through creative destruction

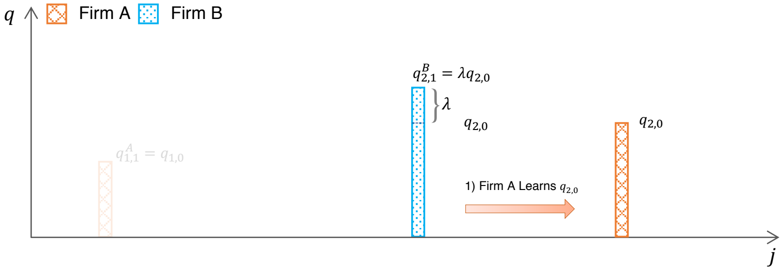
→ **Needs to learn** firm B's technology and get higher q_2

Creative Destruction (period 1)



- But, learning takes time ▸ Detail

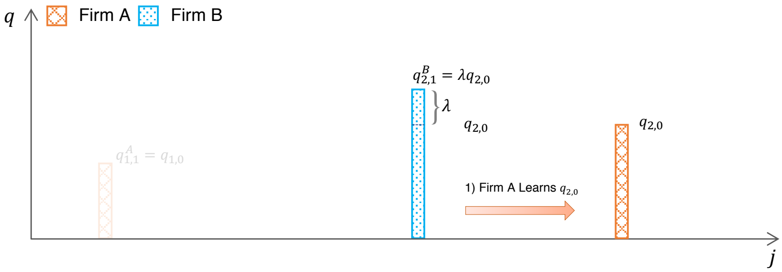
Creative Destruction (period 1)



- But, learning takes time ▸ Detail
- **Assumption (Imperfect technology spillover)**

  Creative destruction builds on past-period technology of incumbent

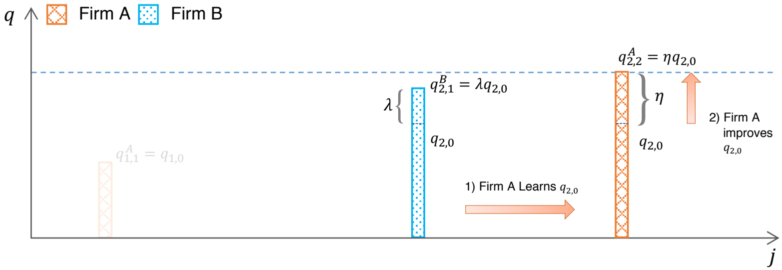
Creative Destruction (period 1)



- But, learning takes time ▸ Detail
- **Assumption (Imperfect technology spillover)**

  Creative destruction builds on past-period technology of incumbent
- **Local technology gap** : $\Delta_{2,1} = \dfrac{q^B_{2,1}}{q_{2,0}}$ summarizes tech. advantage firm B has

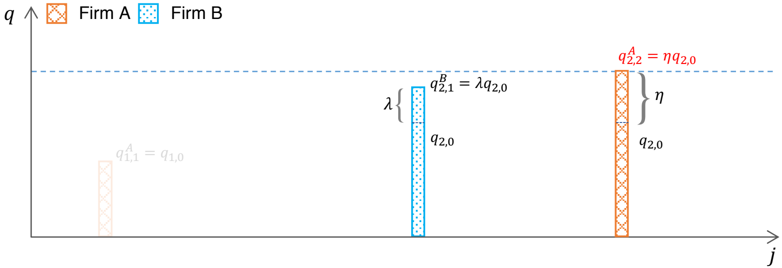
Creative Destruction (period 1)



- As before, R&D investment ($R_{2,1}^{ex}$) $\Rightarrow$ higher success probability of innov. ($x_{2,1}$)
- Successful creative dest. improves $q_{2,0}$ by $\eta > 1$ ($\eta > \lambda$ by AK 2018 and data evidence) Detail

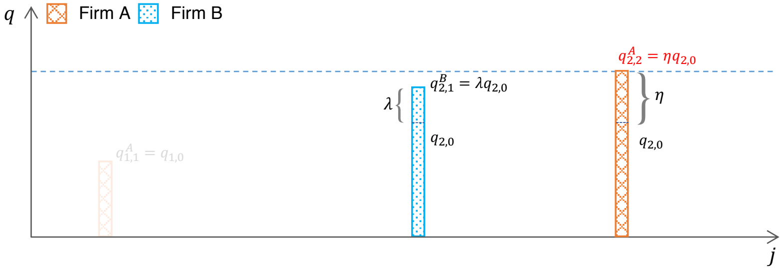
$$q_{2,2}^{A} = \begin{cases} q_{2,0} & \text{w/ prob. } 1 - x_{2,1} \\ \eta q_{2,0} & \text{w/ prob. } x_{2,1} \end{cases}$$

Creative Destruction (period 2)



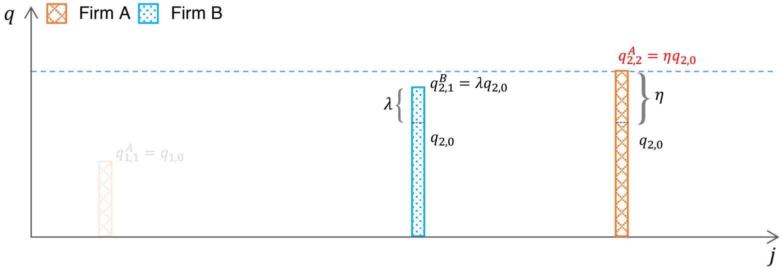
- We are in period 2
- Let's assume firm A made successful creative destruction: $q^A_{2,2} > q^B_{2,1}$

Creative Destruction (period 2)



- We are in period 2
- Let's assume firm A made successful creative destruction: $q^A_{2,2} > q^B_{2,1}$
- Does this mean firm A took over market 2 from firm B?

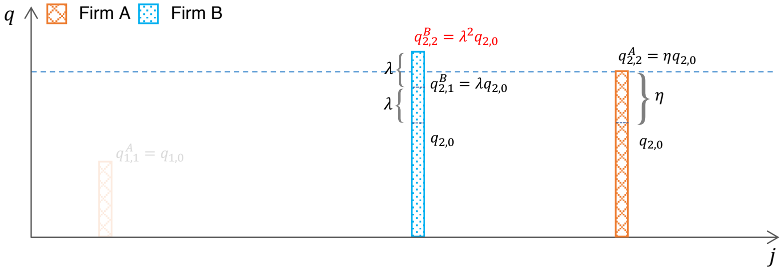
Creative Destruction (period 2)



- We are in period 2
- Let's assume firm *A* made successful creative destruction: $q^A_{2,2} > q^B_{2,1}$
- Does this mean firm A took over market 2 from firm B?
- **NO!** firm B can also do own-innovation for product 2

  → Suppose firm B also succeeds in own-innovation on product 2

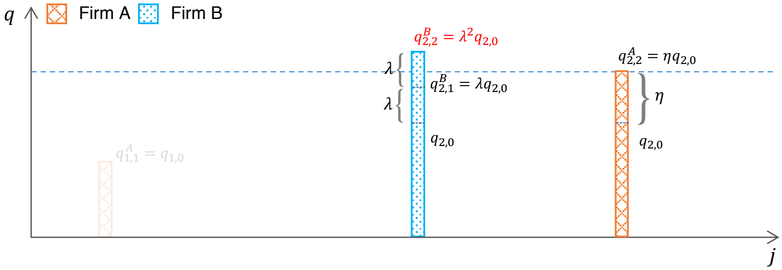
Market Protection (period 2)



- **Assumption:**

Improvement through own-innovation is high enough that $\lambda^2 > \eta$

Market Protection (period 2)

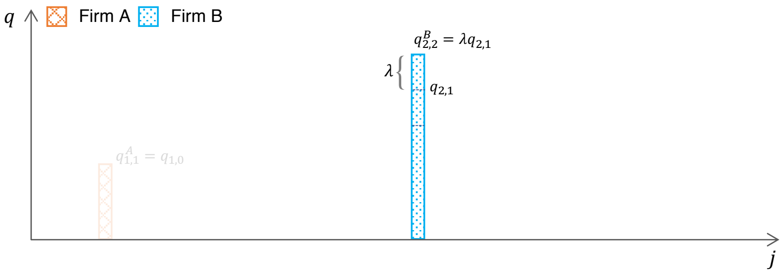


- **Assumption:**

  Improvement through own-innovation is high enough that $\lambda^2 > \eta$

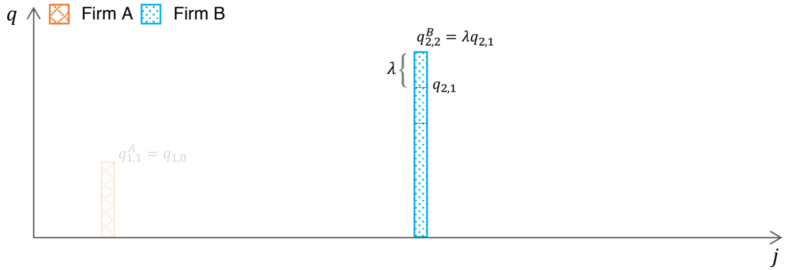
★ Implication: firm B can use tech. advantage accumulated b/w period 0 and 1 to protect its market

Market Protection (period 2)



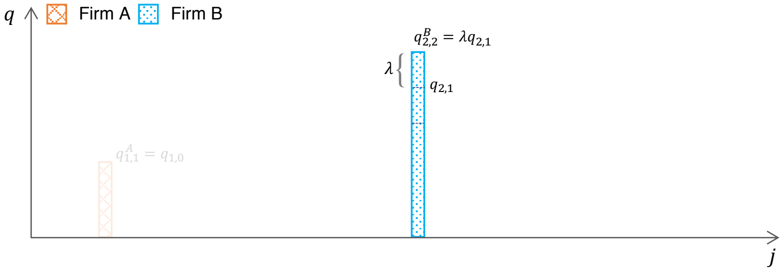
- Firm B succeeds in protecting its own product mkt. 2 from firm A
- Due to the **imperfect technology spillover & technology advantage of firm B**

Market Protection (period 2)



- Firm B succeeds in protecting its own product mkt. 2 from firm A
- Due to the **imperfect technology spillover & technology advantage of firm B**
- ★ Implication: **"endogenously"** affecting the creative destruction of firm A

Market Protection (period 2)



- Firm B succeeds in protecting its own product mkt. 2 from firm A
- Due to the **imperfect technology spillover & technology advantage of firm B**
- ★ Implication: **"endogenously"** affecting the creative destruction of firm A
- If firms do not have enough tech. advantage, they won't be able to protect their markets (firm A)

▶ More

Key Findings

▸ Decision Rules

- **Summary:**

  Competitive pressure = Prob. of facing a competitor in own mkt = Success prob. of creative dest. (x)

Key Findings

Decision Rules

- **Summary:**

  Competitive pressure = Prob. of facing a competitor in own mkt = Success prob. of creative dest. (x)

  1. Prod owners: if $\exists$ tech. advantage $\rightarrow$ own-innovation $\uparrow$ when $x \uparrow$ Proposition 1

     if $\nexists$ tech. advantage $\rightarrow$ not much incentive for own-innovation

Key Findings

Decision Rules

- **Summary:**

  Competitive pressure = Prob. of facing a competitor in own mkt = Success prob. of creative dest. (x)

  1. Prod owners: if $\exists$ tech. advantage $\rightarrow$ own-innovation $\uparrow$ when $x \uparrow$ Proposition 1

     if $\nexists$ tech. advantage $\rightarrow$ not much incentive for own-innovation

  2. Outsiders: if tech. barrier $\uparrow$ in target mkts., not much incentive to do creative destruction Proposition 2

Key Findings

Decision Rules

- **Summary:**

  Competitive pressure = Prob. of facing a competitor in own mkt = Success prob. of creative dest. (x)

  1. Prod owners: if $\exists$ tech. advantage $\rightarrow$ own-innovation $\uparrow$ when $x \uparrow$ Proposition 1

     if $\nexists$ tech. advantage $\rightarrow$ not much incentive for own-innovation

  2. Outsiders: if tech. barrier $\uparrow$ in target mkts., not much incentive to do creative destruction Proposition 2

★ Our full-fledged model has all these features Full-fledged

★ Counterfactual: overall innovation can $\uparrow$ or $\downarrow$ w/ different cost structure Calibration US Non US

★ **Different aggregate** implications depending on **innovation composition**

Table of Contents

Data

- Population of patenting firms or manufacturers in the U.S.

Data

- Population of patenting firms or manufacturers in the U.S.
- **Data sources: US Census Bureau + USPTO**
  1. USPTO PatentsView patent data 1974-2018
  2. The Longitudinal Business Database (LBD) 1976-2016
  3. The Longitudinal Firm Trade Transactions Database (LFTTD) 1992-2016
  4. The Census of Manufacturers (CMF) 1972-2012 (every 5 years)
  5. UN-Comtrade Database 1991-2017
  6. NBER-CES 1974-2011
  7. Feenstra et al. (2002) U.S. Tariff Schedules 1989-2001
- USPTO-LBD crosswalk based on Ding et al. (2022)

  (name and address matching + internet-search aided results as in Autor et al. (2020))

Main Measures

- Firm innovation
  - Citation-adjusted number of patent applications as a proxy for firm innovation
  - **Self-citation ratio** as the likelihood that patents are used for own-innovation (Akcigit and Kerr 2018)

Main Measures

- Firm innovation
  - Citation-adjusted number of patent applications as a proxy for firm innovation
  - **Self-citation ratio** as the likelihood that patents are used for own-innovation (Akcigit and Kerr 2018)
- Learning time
  - **Backward citation gap**: the gap b/w a patent's application year and the application years of the patents it cites (Jaffe et al. 1993)

Main Measures

- Firm innovation
  - Citation-adjusted number of patent applications as a proxy for firm innovation
  - **Self-citation ratio** as the likelihood that patents are used for own-innovation (Akcigit and Kerr 2018)
- Learning time
  - **Backward citation gap**: the gap b/w a patent's application year and the application years of the patents it cites (Jaffe et al. 1993)
- Competition shock

▸ More

  - Removal of uncertainty about U.S. trade policy toward China on imposed tariff rates after China's WTO accession in 2001 (Pierce and Schott 2016, Handley and Limão 2017)

$$\textbf{NTR Gap}_j = \underbrace{\textit{Non-NTR Rate}_j}_{\text{for non-mkt econ., avg. 37\%}} - \underbrace{\textit{NTR Rate}_j}_{\text{for WTO members, avg. 4\%}}$$

⁎ Use **NTR Gap**$_j$ measured in 1999 (a year before the US gov. granted Permanent-NTR status to China)

Heterogeneity in Firm Innovation: Learning Time

▸ Robustness

- $CitationGap_{ipct} = \alpha + \beta SelfCite_{ipct} + \delta_{it} + \delta_{ct} + \varepsilon_{ipct}$
  - $CitationGap_{ipct}$: avg. backward citation gap for patents cited by firm i's patent p in cpc c, year t
  - $SelfCite_{ipct}$: self-citation ratio of patent p; δ_{it}: firm-year FE; δ_{ct}: cpc-year FE

Heterogeneity in Firm Innovation: Learning Time

▸ Robustness

- $CitationGap_{ipct} = \alpha + \beta SelfCite_{ipct} + \delta_{it} + \delta_{ct} + \varepsilon_{ipct}$
  - $CitationGap_{ipct}$: avg. backward citation gap for patents cited by firm i's patent p in cpc c, year t
  - $SelfCite_{ipct}$: self-citation ratio of patent p; δ_{it}: firm-year FE; δ_{ct}: cpc-year FE

	Citation gaps	Citation gaps	Citation gaps
Self-citation ratio	-2.290***	-2.450***	-2.592***
	(0.018)	(0.018)	(0.020)
Observations	728,721	728,721	728,721
Fixed effects	none	ct	it, ct

Heterogeneity in Firm Innovation: Learning Time

▸ Robustness

- $CitationGap_{ipct} = \alpha + \beta SelfCite_{ipct} + \delta_{it} + \delta_{ct} + \varepsilon_{ipct}$
  - $CitationGap_{ipct}$: avg. backward citation gap for patents cited by firm i's patent p in cpc c, year t
  - $SelfCite_{ipct}$: self-citation ratio of patent p; δ_{it}: firm-year FE; δ_{ct}: cpc-year FE

	Citation gaps	Citation gaps	Citation gaps
Self-citation ratio	-2.290***	-2.450***	-2.592***
	(0.018)	(0.018)	(0.020)
Observations	728,721	728,721	728,721
Fixed effects	none	ct	it, ct

★ Patents assoc. w/ creative destruction take longer to develop from existing technologies

Heterogeneity in Firm Innovation: Quality Improvement

- $Quality_{ipct} = \alpha + \beta_1 SelfCite_{ipct} + \beta_2 X_{it-1} + \delta_{ct} + \varepsilon_{ipct}$
  - $Quality_{ipct}$: log market value (M-value) or # forward citations (S-value) for firm i's patent p in cpc c, year t
  - $SelfCite_{ipct}$: self-citation ratio of firm i's patent p; X_{it-1}: firm size at $t-1$; δ_{ct}: cpc-year FE

Heterogeneity in Firm Innovation: Quality Improvement

- $Quality_{ipct} = \alpha + \beta_1 SelfCite_{ipct} + \beta_2 X_{it-1} + \delta_{ct} + \varepsilon_{ipct}$
  - $Quality_{ipct}$: log market value (M-value) or # forward citations (S-value) for firm i's patent p in cpc c, year t
  - $SelfCite_{ipct}$: self-citation ratio of firm i's patent p; X_{it-1}: firm size at $t-1$; δ_{ct}: cpc-year FE

	M-value	M-value	S-value	S-value
Self-citation	-0.289***	-0.027***	-0.082***	-0.047***
	(0.006)	(0.005)	(0.008)	(0.008)
Market cap_{-1}	0.431***	0.289***	-0.025***	-0.043***
	(0.001)	(0.003)	(0.001)	(0.005)
Observations	360,750	360,750	360,750	360,750
Fixed effects	ct	i, ct	ct	i, ct

Heterogeneity in Firm Innovation: Quality Improvement

- $Quality_{ipct} = \alpha + \beta_1 SelfCite_{ipct} + \beta_2 X_{it-1} + \delta_{ct} + \varepsilon_{ipct}$
  - $Quality_{ipct}$: log market value (M-value) or # forward citations (S-value) for firm i's patent p in cpc c, year t
  - $SelfCite_{ipct}$: self-citation ratio of firm i's patent p; X_{it-1}: firm size at $t-1$; δ_{ct}: cpc-year FE

	M-value	M-value	S-value	S-value
Self-citation	-0.289***	-0.027***	-0.082***	-0.047***
	(0.006)	(0.005)	(0.008)	(0.008)
Market cap$_{-1}$	0.431***	0.289***	-0.025***	-0.043***
	(0.001)	(0.003)	(0.001)	(0.005)
Observations	360,750	360,750	360,750	360,750
Fixed effects	ct	i, ct	ct	i, ct

★ Patents assoc. w/ creative destruction are of higher quality than own-innovations

Heterogeneity in Firm Innovation: Economic Outcome

▸ Robustness

- $\Delta Y_{ijt+5} = \beta_1 Pat_{ijt} + \beta_2 Self_{ijt} + \mathbf{X}_{ijt}\gamma_1 + \delta_{jt+5} + \varepsilon_{ijt+5}$
  - $Quality_{ipct}$: DHS growth of emp, productivity, # industries/products added, and within-firm product market concentration b/w t, $t+5$
  - Pat_{ijt}: citation-adjusted number of patents (in log) at t
  - $Self_{ijt}$: citation-adjusted avg. self-citation ratio at t for firm i in industry j
  - $\mathbf{X}_{ijt}$: covariates for firm size, age, tech. class-level past patenting trend, public firm status

Heterogeneity in Firm Innovation: Economic Outcome

▸ Robustness

- $\Delta Y_{ijt+5} = \beta_1 Pat_{ijt} + \beta_2 Self_{ijt} + \mathbf{X}_{ijt}\gamma_1 + \delta_{jt+5} + \varepsilon_{ijt+5}$
  - $Quality_{ipct}$: DHS growth of emp, productivity, # industries/products added, and within-firm product market concentration b/w t, $t+5$
  - Pat_{ijt}: citation-adjusted number of patents (in log) at t
  - $Self_{ijt}$: citation-adjusted avg. self-citation ratio at t for firm i in industry j
  - $\mathbf{X}_{ijt}$: covariates for firm size, age, tech. class-level past patenting trend, public firm status

	ΔEmployment	#Industries added	#Products added	ΔHHI
#patents	0.036***	0.102***	0.358**	-0.012
	(0.010)	(0.011)	(0.085)	(0.023)
Avg. self-citation	-0.256**	-0.158**	-0.274***	0.154**
	(0.109)	(0.079)	(0.102)	(0.069)
Observations	5,400	5,400	5,700	5,700
Fixed effects	jt	jt	jt	jt

Heterogeneity in Firm Innovation: Economic Outcome

▸ Robustness

- $\Delta Y_{ijt+5} = \beta_1 Pat_{ijt} + \beta_2 Self_{ijt} + \mathbf{X}_{ijt}\gamma_1 + \delta_{jt+5} + \varepsilon_{ijt+5}$
  - $Quality_{ipct}$: DHS growth of emp, productivity, # industries/products added, and within-firm product market concentration b/w t, $t+5$
  - Pat_{ijt}: citation-adjusted number of patents (in log) at t
  - $Self_{ijt}$: citation-adjusted avg. self-citation ratio at t for firm i in industry j
  - $\mathbf{X}_{ijt}$: covariates for firm size, age, tech. class-level past patenting trend, public firm status

	ΔEmployment	#Industries added	#Products added	ΔHHI
#patents	0.036***	0.102***	0.358**	-0.012
	(0.010)	(0.011)	(0.085)	(0.023)
Avg. self-citation	-0.256**	-0.158**	-0.274***	0.154**
	(0.109)	(0.079)	(0.102)	(0.069)
Observations	5,400	5,400	5,700	5,700
Fixed effects	jt	jt	jt	jt

★ (+) corr. b/w patenting and firm growth gets dampened & higher product HHI for own-innovation

Market-Protection Effect

▸ Summary stat. ▸ Trade shocks

- Generalized Diff-in-diff as in PS 2016 (with DD term interacted with innovation intensity)

$$\Delta y_{ijp} = \beta_1 Post_p \times NTR\ Gap_{ijp0} \times InnovIntens_{ijp0} + \beta_2 Post_p \times NTR\ Gap_{ijp0} + \beta_3 Post_p \times InnovIntens_{ijp0}$$

$$+\beta_4 NTR\ Gap_{ijp0} \times InnovIntens_{ijp0} + \beta_5 NTR\ Gap_{ijp0} + \beta_6 InnovIntens_{ijp0} + \mathbf{X}_{ijp0}\,\gamma_1 + \mathbf{X}_{jp0}\,\gamma_2 + \delta_j + \delta_p + \alpha + \varepsilon_{ijp}\,.$$

  - i: firm, j: main 6-digit NAICS industry firm i belongs to, p: time period (1992–1999, 2000–2007)
  - Δy_{ijp} : 7yr DHS growth of i) No. patents firm applied each year, ii) avg. self-citation ratio

Market-Protection Effect

▸ Summary stat. ▸ Trade shocks

- Generalized Diff-in-diff as in PS 2016 (with DD term interacted with innovation intensity)

$$\Delta y_{ijp} = \beta_1 Post_p \times NTR\ Gap_{ijp0} \times InnovIntens_{ijp0} + \beta_2 Post_p \times NTR\ Gap_{ijp0} + \beta_3 Post_p \times InnovIntens_{ijp0}$$

$$+ \beta_4 NTR\ Gap_{ijp0} \times InnovIntens_{ijp0} + \beta_5 NTR\ Gap_{ijp0} + \beta_6 InnovIntens_{ijp0} + \mathbf{X}_{ijp0}\,\gamma_1 + \mathbf{X}_{jp0}\,\gamma_2 + \delta_j + \delta_p + \alpha + \varepsilon_{ijp}\,.$$

  - i: firm, j: main 6-digit NAICS industry firm i belongs to, p: time period (1992–1999, 2000–2007)
  - Δy_{ijp} : 7yr DHS growth of i) No. patents firm applied each year, ii) avg. self-citation ratio
  - $NTR\ Gap_{ijp0}$: emp.-wgted avg. of 1999 industry-level NTR gaps across all the industries firm operates, measured in the start year for each period $p0$ (first diff.)
  - $Post_p$: Dummy equal to one for p = 2000–2007, post treatment period (second diff.)

Market-Protection Effect

▸ Summary stat. ▸ Trade shocks

- Generalized Diff-in-diff as in PS 2016 (with DD term interacted with innovation intensity)

$$\Delta y_{ijp} = \beta_1 Post_p \times NTR\ Gap_{ijp0} \times InnovIntens_{ijp0} + \beta_2 Post_p \times NTR\ Gap_{ijp0} + \beta_3 Post_p \times InnovIntens_{ijp0}$$

$$+ \beta_4 NTR\ Gap_{ijp0} \times InnovIntens_{ijp0} + \beta_5 NTR\ Gap_{ijp0} + \beta_6 InnovIntens_{ijp0} + \mathbf{X}_{ijp0}\,\gamma_1 + \mathbf{X}_{jp0}\,\gamma_2 + \delta_j + \delta_p + \alpha + \varepsilon_{ijp}\,.$$

  - i: firm, j: main 6-digit NAICS industry firm i belongs to, p: time period (1992–1999, 2000–2007)
  - Δy_{ijp} : 7yr DHS growth of i) No. patents firm applied each year, ii) avg. self-citation ratio
  - $NTR\ Gap_{ijp0}$: emp.-wgted avg. of 1999 industry-level NTR gaps across all the industries firm operates, measured in the start year for each period $p0$ (first diff.)
  - $Post_p$: Dummy equal to one for p = 2000–2007, post treatment period (second diff.)
  - $InnovIntens_{ijp0}$: avg. of past 5yr innovation intensity (nb. of patents / emp) measured in $p0$

Market-Protection Effect

Summary stat. Trade shocks

- Generalized Diff-in-diff as in PS 2016 (with DD term interacted with innovation intensity)

$$\Delta y_{ijp} = \beta_1 Post_p \times NTR\ Gap_{ijp0} \times InnovIntens_{ijp0} + \beta_2 Post_p \times NTR\ Gap_{ijp0} + \beta_3 Post_p \times InnovIntens_{ijp0}$$

$$+ \beta_4 NTR\ Gap_{ijp0} \times InnovIntens_{ijp0} + \beta_5 NTR\ Gap_{ijp0} + \beta_6 InnovIntens_{ijp0} + X_{ijp0}\gamma_1 + X_{jp0}\gamma_2 + \delta_j + \delta_p + \alpha + \varepsilon_{ijp} .$$

  - i: firm, j: main 6-digit NAICS industry firm i belongs to, p: time period (1992–1999, 2000–2007)
  - Δy_{ijp} : 7yr DHS growth of i) No. patents firm applied each year, ii) avg. self-citation ratio
  - $NTR\ Gap_{ijp0}$: emp.-wgted avg. of 1999 industry-level NTR gaps across all the industries firm operates, measured in the start year for each period $p0$ (first diff.)
  - $Post_p$: Dummy equal to one for p = 2000–2007, post treatment period (second diff.)
  - $InnovIntens_{ijp0}$: avg. of past 5yr innovation intensity (nb. of patents / emp) measured in $p0$
  - X_{ijp0}, X_{jp0} : covariates for firm size, age, tech. class-level past patenting trend, public firm status, NTR rate
  - δ_j, δ_p: industry, time fixed effects

Market-Protection Effect

▸ Summary stat. ▸ Trade shocks

- Generalized Diff-in-diff as in PS 2016 (with DD term interacted with innovation intensity)

$$\Delta y_{ijp} = \beta_1 Post_p \times NTR\ Gap_{ijp0} \times InnovIntens_{ijp0} + \beta_2 Post_p \times NTR\ Gap_{ijp0} + \beta_3 Post_p \times InnovIntens_{ijp0}$$

$$+ \beta_4 NTR\ Gap_{ijp0} \times InnovIntens_{ijp0} + \beta_5 NTR\ Gap_{ijp0} + \beta_6 InnovIntens_{ijp0} + \mathbf{X}_{ijp0}\,\gamma_1 + \mathbf{X}_{jp0}\,\gamma_2 + \delta_j + \delta_p + \alpha + \varepsilon_{ijp}\,.$$

  - i: firm, j: main 6-digit NAICS industry firm i belongs to, p: time period (1992–1999, 2000–2007)
  - Δy_{ijp} : 7yr DHS growth of i) No. patents firm applied each year, ii) avg. self-citation ratio
  - $NTR\ Gap_{ijp0}$: emp.-wgted avg. of 1999 industry-level NTR gaps across all the industries firm operates, measured in the start year for each period $p0$ (first diff.)
  - $Post_p$: Dummy equal to one for p = 2000–2007, post treatment period (second diff.)
  - $InnovIntens_{ijp0}$: avg. of past 5yr innovation intensity (nb. of patents / emp) measured in $p0$
  - $\mathbf{X}_{ijp0}, \mathbf{X}_{jp0}$: covariates for firm size, age, tech. class-level past patenting trend, public firm status, NTR rate
  - δ_j, δ_p: industry, time fixed effects

- Model implies: $\beta_1 > 0$ for ΔSelf-citation ratio

Market-Protection Effect

▸ No ctrls ▸ Robustness

	ΔPatents	ΔPatents
	(1)	(2)
NTR gap × Post	0.067	0.071
	(0.275)	(0.283)
× Innovation intensity		-0.054
		(0.242)
Observations	6,500	6,500
Fixed effects	j, p	j, p
Controls	full	full

- No statistical impacts on overall innovation → mixed effects on diff. types

Market-Protection Effect

▸ No ctrls ▸ Robustness

	ΔPatents	ΔPatents	ΔSelf-cite	ΔSelf-cite
	(1)	(2)	(3)	(4)
NTR gap × Post	0.067	0.071	0.045	-0.062
	(0.275)	(0.283)	(0.291)	(0.291)
× Innovation intensity		-0.054		0.795***
		(0.242)		(0.277)
Observations	6,500	6,500	6,500	6,500
Fixed effects	j, p	j, p	j, p	j, p
Controls	full	full	full	full

- No statistical impacts on overall innovation and composition → mixed effects on diff. types
- ★ **BUT, firms with tech. advantage increase own-innovation under foreign competitive pressure**

Market-Protection Effect

▸ No ctrls ▸ Robustness

	ΔPatents	ΔPatents	ΔSelf-cite	ΔSelf-cite
	(1)	(2)	(3)	(4)
NTR gap × Post	0.067	0.071	0.045	-0.062
	(0.275)	(0.283)	(0.291)	(0.291)
× Innovation intensity		-0.054		0.795***
		(0.242)		(0.277)
Observations	6,500	6,500	6,500	6,500
Fixed effects	j, p	j, p	j, p	j, p
Controls	full	full	full	full

- No statistical impacts on overall innovation and composition → mixed effects on diff. types
- ★ BUT, firms with tech. advantage increase own-innovation under foreign competitive pressure
- (+) corr. b/w patenting and Δemp gets dampened by **17.1%** due to own-innovation ↑ ▸ Details

Market-Protection Effect

No ctrls | Robustness

	ΔPatents	ΔPatents	ΔSelf-cite	ΔSelf-cite
	(1)	(2)	(3)	(4)
NTR gap × Post	0.067	0.071	0.045	-0.062
	(0.275)	(0.283)	(0.291)	(0.291)
× Innovation intensity		-0.054		0.795***
		(0.242)		(0.277)
Observations	6,500	6,500	6,500	6,500
Fixed effects	j, p	j, p	j, p	j, p
Controls	full	full	full	full

- No statistical impacts on overall innovation and composition → mixed effects on diff. types
- ★ BUT, firms with tech. advantage increase own-innovation under foreign competitive pressure
- (+) corr. b/w patenting and Δemp gets dampened by **17.1%** due to own-innovation ↑ — Details
- Similar patterns hold for # **of products added** or **product concentration** — Results

Technological Barrier Effect

	Firm entry	Firm entry
Technological barriers	-0.012**	-0.016**
	(0.006)	(0.007)
Observation	1,300	1,300
Fixed effects	j, t	j, t
Tech. barrier thresholds	5pc	10pc

- Our model also predicts that firm entry falls with higher technological barriers in the economy.

$$FirmEntry_{jt} = \beta TechBarrier_{jt} + \delta_j + \delta_t + \alpha + \varepsilon_{jt}.$$

  - $FirmEntry_{jt}$: firm entry rate in industry j at year t
  - $TechBarrier_{jt}$: top 5 or 10 pctl of the inverse of firm-level TFPR gap from the frontier in ind. j at t

Technological Barrier Effect

	Firm entry	Firm entry
Technological barriers	-0.012**	-0.016**
	(0.006)	(0.007)
Observation	1,300	1,300
Fixed effects	j, t	j, t
Tech. barrier thresholds	5pc	10pc

- Our model also predicts that firm entry falls with higher technological barriers in the economy.

$$FirmEntry_{jt} = \beta TechBarrier_{jt} + \delta_j + \delta_t + \alpha + \varepsilon_{jt}.$$

  - $FirmEntry_{jt}$: firm entry rate in industry j at year t
  - $TechBarrier_{jt}$: top 5 or 10 pctl of the inverse of firm-level TFPR gap from the frontier in ind. j at t

★ Find negative corr. b/w firm entry rate and technological barriers

Table of Contents

Full-fledged Model (extension of Akcigit and Kerr (2018))

- Discrete-time Endogenous growth General Equilibrium Firm Innovation Model
- Multi-product firms competing over market ownership via tech. leadership
  - Continuum of differentiated products (owned by firms)
- **Two types** of firm innovation
  - Own-innov.: improves firm's own product current period quality (technology) by $\lambda > 1$
  - Creative dest. : improves other products' past period quality (technology) by $\eta > \lambda$ $\lambda^2 > \eta$
- Imperfect technology spillover
  - Lagged learning : firms can only learn other firms' past period technology
  - Generates technology gap in each product market, $\Delta_j = \dfrac{\text{current period technology}}{\text{past period technology}}$

Full-fledged Model (extension of Akcigit and Kerr (2018))

- Discrete-time Endogenous growth General Equilibrium Firm Innovation Model
- Multi-product firms competing over market ownership via tech. leadership
  - Continuum of differentiated products (owned by firms)
- **Two types** of firm innovation
  - Own-innov.: improves firm's own product current period quality (technology) by $\lambda > 1$
  - Creative dest. : improves other products' past period quality (technology) by $\eta > \lambda \; \lambda^2 > \eta$
- Imperfect technology spillover
  - Lagged learning : firms can only learn other firms' past period technology
  - Generates technology gap in each product market, $\Delta_j = \dfrac{\text{current period technology}}{\text{past period technology}}$
- Endogenous firm entry and exit
- Exogenous competitive pressure by outside firms
  - Creative destruction arrival rate: $\bar{x} = \bar{x}_d + \bar{x}_o$

CALIBRATION

Key Findings

- Target: U.S. manufacturing firms (1992)
  - Sources: Akcigit and Kerr (2018), Schott (2008), CMF, LBD

#	Parameter	Description	Value	Identification	Data	Model
1.	β	Time discount rate	0.947	Annual interest rate of 5.6%		
2.	$\widehat{\psi}$	Curvature of own-innov. R&D	2	Akcigit and Kerr (2018)		
3.	$\widetilde{\psi}$	Curvature of CD R&D	2	Akcigit and Kerr (2018)		
4.	$\widetilde{\psi}^e$	Curvature of CD R&D, startup	2	Akcigit and Kerr (2018)		
5.	θ	Quality share in final goods production	0.109	Data		
6.	$\widehat{\chi}$	Scale of own-innov. R&D	0.044	Avg. # of products,	2.3	2.3
7.	$\widetilde{\chi}$	Scale of CD R&D	0.405	# of products added	0.3	0.3
8.	$\widetilde{\chi}^e$	Scale of CD R&D, startup	1.689	Firm entry rate	7.6	7.6
9.	λ	Quality multiplier of own-innov.	1.040	Agg. productivity growth rate,	1.9	1.9
10.	η	Quality multiplier of CD	1.075	H-G firm growth rate	22.5	22.3
11.	ε_O	Mass of outside entrants	0.043	Import penetration (manuf.)	15.3	15.3

Counterfactual: Competitive Pressure in the U.S.

Key Findings

description	variables	before	after	% change
creative destruction arrival rate by outside firms (%)	$\bar{x}_o$	3.3	5.5	66.4%
aggregate creative destruction arrival rate (%)	$\bar{x}$	21.5	21.9	1.51%
prob. of own-innov. ($\Delta^1 = 1$, %)	z^1	16.9	16.8	-0.43%
prob. of own-innov. ($\Delta^2 = \lambda$, %)	z^2	57.8	57.9	0.19%
prob. of own-innov. ($\Delta^3 = \eta$, %)	z^3	39.7	39.7	0.13%
prob. of own-innov. ($\Delta^4 = \frac{\eta}{\lambda}$, %)	z^4	37.3	37.4	0.05%
prob. of creative dest., incumbents (%)	x	16.8	16.5	-1.33%
prob. of creative dest., potential startups (%)	x_e	4.02	3.97	-1.33%
R&D to sales ratio (%)		4.6	4.5	-1.6%
aggregate growth rate by domestic firms (%)		1.9	1.7	-11.0%

- 66.4% increase in $\bar{x}_o$ increase the import penetration ratio from 1992-level (15.3%) to 2007-level (25.1%)

Counterfactual: Competitive Pressure in the U.S.

Key Findings

description	variables	before	after	% change
creative destruction arrival rate by outside firms (%)	$\bar{x}_o$	3.3	5.5	66.4%
aggregate creative destruction arrival rate (%)	$\bar{x}$	21.5	21.9	1.51%
prob. of own-innov. ($\Delta^1 = 1$, %)	z^1	16.9	16.8	-0.43%
prob. of own-innov. ($\Delta^2 = \lambda$, %)	z^2	57.8	57.9	0.19%
prob. of own-innov. ($\Delta^3 = \eta$, %)	z^3	39.7	39.7	0.13%
prob. of own-innov. ($\Delta^4 = \frac{\eta}{\lambda}$, %)	z^4	37.3	37.4	0.05%
prob. of creative dest., incumbents (%)	x	16.8	16.5	-1.33%
prob. of creative dest., potential startups (%)	x_e	4.02	3.97	-1.33%
R&D to sales ratio (%)		4.6	4.5	-1.6%
aggregate growth rate by domestic firms (%)		1.9	1.7	-11.0%

- 66.4% increase in $\bar{x}_o$ increase the import penetration ratio from 1992-level (15.3%) to 2007-level (25.1%)
- Own-innov. ↑ for $\Delta^\ell > 1$, ↓ for $\Delta^\ell = 1$; Creative dest. ↓: **innovation composition** changes!

Counterfactual: Competitive Pressure in the U.S.

◂ Key Findings

description	variables	before	after	% change
creative destruction arrival rate by outside firms (%)	$\bar{x}_o$	3.3	5.5	66.4%
aggregate creative destruction arrival rate (%)	$\bar{x}$	21.5	21.9	1.51%
prob. of own-innov. ($\Delta^1 = 1$, %)	z^1	16.9	16.8	-0.43%
prob. of own-innov. ($\Delta^2 = \lambda$, %)	z^2	57.8	57.9	0.19%
prob. of own-innov. ($\Delta^3 = \eta$, %)	z^3	39.7	39.7	0.13%
prob. of own-innov. ($\Delta^4 = \frac{\eta}{\lambda}$, %)	z^4	37.3	37.4	0.05%
prob. of creative dest., incumbents (%)	x	16.8	16.5	-1.33%
prob. of creative dest., potential startups (%)	x_e	4.02	3.97	-1.33%
R&D to sales ratio (%)		4.6	4.5	-1.6%
aggregate growth rate by domestic firms (%)		1.9	1.7	-11.0%

- 66.4% increase in $\bar{x}_o$ increase the import penetration ratio from 1992-level (15.3%) to 2007-level (25.1%)
- Own-innov. ↑ for $\Delta^\ell > 1$, ↓ for $\Delta^\ell = 1$; Creative dest. ↓: **innovation composition** changes!
- **Aggregate innovation**: R&D to sales ratio **drops** as creative dest. ↓↓ >> own-innov. ↑
- **Aggregate Growth**: aggregate growth by domestic firms **declines**

Counterfactual: Less Creative Economy ($\tilde{\chi} \times 80$)

Key Findings

description	variables	before	after	% change
creative destruction arrival rate by outside firms (%)	$\bar{x}_o$	1.361	2.406	76.8%
aggregate creative destruction arrival rate (%)	$\bar{x}$	8.966	9.636	7.5%
prob. of own-innov. ($\Delta^1 = 1$, %)	z^1	20.581	20.300	-1.4%
prob. of own-innov. ($\Delta^2 = \lambda$, %)	z^2	50.357	51.024	1.3%
prob. of own-innov. ($\Delta^3 = \eta$, %)	z^3	36.483	36.744	0.7%
prob. of own-innov. ($\Delta^4 = \frac{\eta}{\lambda}$, %)	z^4	35.469	35.662	0.5%
prob. of creative dest., incumbents (%)	x	0.380	0.363	-4.6%
prob. of creative dest., potential startups (%)	x_e	7.285	6.954	-4.6%
R&D to sales ratio (%)		1.39	1.41	1.0%
aggregate growth rate by domestic firms (%)		1.4	1.3	-9.7%

- The implications for firm-level own-innov./creative dest. remain the same

Counterfactual: Less Creative Economy ($\tilde{\chi} \times 80$)

Key Findings

description	variables	before	after	% change
creative destruction arrival rate by outside firms (%)	$\bar{x}_o$	1.361	2.406	76.8%
aggregate creative destruction arrival rate (%)	$\bar{x}$	8.966	9.636	7.5%
prob. of own-innov. ($\Delta^1 = 1$, %)	z^1	20.581	20.300	-1.4%
prob. of own-innov. ($\Delta^2 = \lambda$, %)	z^2	50.357	51.024	1.3%
prob. of own-innov. ($\Delta^3 = \eta$, %)	z^3	36.483	36.744	0.7%
prob. of own-innov. ($\Delta^4 = \frac{\eta}{\lambda}$, %)	z^4	35.469	35.662	0.5%
prob. of creative dest., incumbents (%)	x	0.380	0.363	-4.6%
prob. of creative dest., potential startups (%)	x_e	7.285	6.954	-4.6%
R&D to sales ratio (%)		1.39	1.41	1.0%
aggregate growth rate by domestic firms (%)		1.4	1.3	-9.7%

- The implications for firm-level own-innov./creative dest. remain the same
- However, **aggregate** innovation **increases** (R&D to sales ratio ↑) as creative dest. ↓ << own-innov. ↑↑
- But, aggregate growth by domestic firms decline

Counterfactual: Less Creative Economy ($\tilde{\chi} \times 80$)

Key Findings

description	variables	before	after	% change
creative destruction arrival rate by outside firms (%)	$\bar{x}_o$	1.361	2.406	76.8%
aggregate creative destruction arrival rate (%)	$\bar{x}$	8.966	9.636	7.5%
prob. of own-innov. ($\Delta^1 = 1$, %)	z^1	20.581	20.300	-1.4%
prob. of own-innov. ($\Delta^2 = \lambda$, %)	z^2	50.357	51.024	1.3%
prob. of own-innov. ($\Delta^3 = \eta$, %)	z^3	36.483	36.744	0.7%
prob. of own-innov. ($\Delta^4 = \frac{\eta}{\lambda}$, %)	z^4	35.469	35.662	0.5%
prob. of creative dest., incumbents (%)	x	0.380	0.363	-4.6%
prob. of creative dest., potential startups (%)	x_e	7.285	6.954	-4.6%
R&D to sales ratio (%)		1.39	1.41	1.0%
aggregate growth rate by domestic firms (%)		1.4	1.3	-9.7%

- The implications for firm-level own-innov./creative dest. remain the same
- However, **aggregate** innovation **increases** (R&D to sales ratio ↑) as creative dest. ↓ << own-innov. ↑↑
- But, aggregate growth by domestic firms decline

★ Examining innovation composition matters! — overall innov. ↑ may NOT necessarily be beneficial

Table of Contents

Concluding Remarks

- Introduce imperfect technology spillover to endog. growth literature to study
  - Firms' innovation incentives for diff. types of innov. in richer environment
  - How firms can use diff. types of innovation to survive increased competition
  - How the composition change matters for aggregate innovation and growth
- Increasing competitive pressure induces:
  - Innovative firms to increase internal innov. and higher technological barrier on avg.
  - External innov. to drop overall, leading to decline in firm entry
  - Overall impact depends on innovation composition changes (e.g., the costs of external innov.)
- Extension in progress:
  - Explore cross-country comparison using Orbis data
  - Explore how this interacts with labor market conditions

THANK YOU! ☺

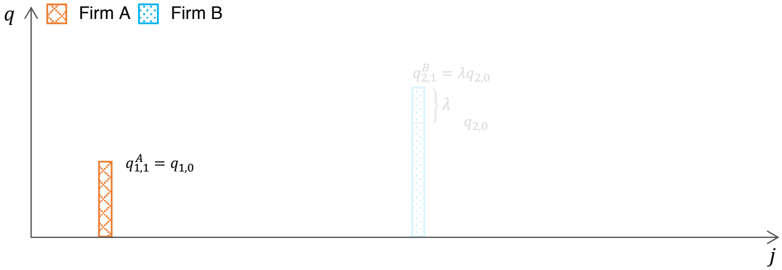
karamjo@gmail.com

seulakim@psu.edu

Appendix

Market Protection w/o Tech. Advantage (period 1)

Main

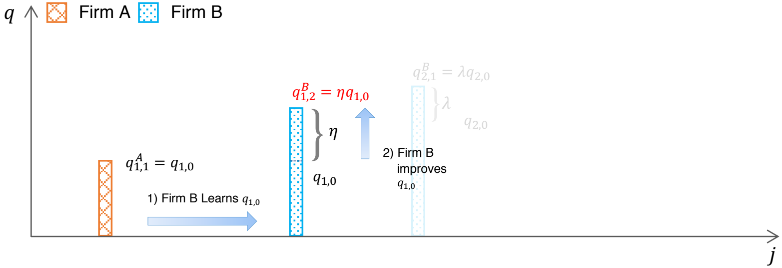


- Now, going back to period 1
- Recall that firm A had no successful innovation b/w period 0 and 1

⟹ No tech. advantage in its own mkt. 1

Market Protection w/o Tech. Advantage (period 1)

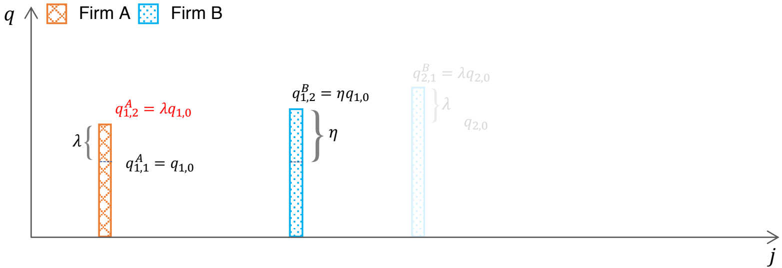
Main



- Suppose firm B conducts creative destruction to target prod mkt. 1

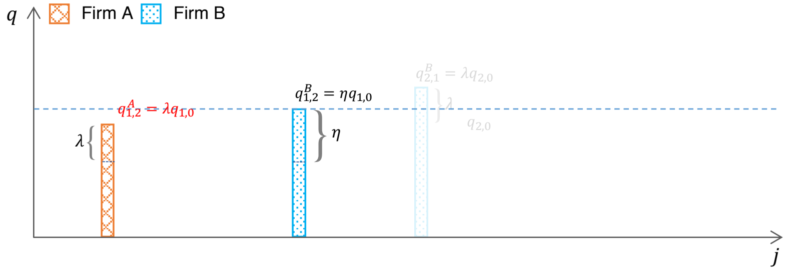
⇒ Firm B needs to learn $q_{1,0} = q^A_{1,1}$, then improves it

Market Protection w/o Tech. Advantage (period 1)



- As before, firm A can also simultaneously do own-innov. from $q^A_{1,1} = q_{1,0}$

Market Protection w/o Tech. Advantage (period 1)



- Let's say both firm A and B succeed innovation. But $q^B_{1,2} > q^A_{1,2}$
- Thus, firm B succeeds in taking over firm A's prod. mkt. 1

  i.e., firm A fails to protect its prod. mkt 1 from firm B even w/ successful int. innov.
- Why? Firm A failed to accumulate tech. advantage in prod. mkt. 1

★ **Implication: Firms w/ no tech. advantage don't have incentive for market-protection**

Optimal Decision Rules

▸ Assump. ▸ Innov. Prob.

$$z^*_{2,1} = \begin{cases} \frac{\pi_{2,2}}{2\,\widehat{\chi}}\lambda(1 - x_{2,1}) & \text{, when } q_{2,1} = q_{2,0} \\ \frac{\pi_{2,2}}{2\,\widehat{\chi}}\left[1 + \lambda - (1 - x_{2,1})\right] & \text{, when } q_{2,1} = \lambda\, q_{2,0} \\ \frac{\pi_{2,2}}{2\,\widehat{\chi}}\lambda & \text{, when } q_{2,1} = \eta\, q_{2,0}, \end{cases} \qquad x^*_{1,1} = \begin{cases} \frac{\eta\,\pi_{1,2}}{\widetilde{\psi}\,\widetilde{\chi}} & \text{, when } q_{1,1} = q_{1,0} \\ \frac{\eta\,\pi_{1,2}}{\widetilde{\psi}\,\widetilde{\chi}}(1 - z_{1,1}) & \text{, when } q_{1,1} = \lambda\, q_{1,0} \\ 0 & \text{, when } q_{1,1} = \eta\, q_{1,0} \end{cases}$$

- $\pi_{j,2}$: normalized profit in period 2, $z_{j,1}$: own-innov. intensity $x_{j,1}$: creative dest. intensity
- $x_{2,1}$ can be interpreted as prob. of meeting a competitor in own mkt – competitive pressure!
- Hetero. response of opt. own-innov. decision on competition based on tech. advantage
- Hetero. level of opt. creative dest. decision based on tech. barrier

◂ Main

Simplifying Assumptions

Focus on firm 1's innovation problem, solve for a partial equilibrium

1. Profit from production is linear in technology, $\pi q_{1,1}$ and $\pi' q_{1,2}$
2. Firm 1 has advantage in its own market 1

   $\Rightarrow$ if $q^1_{1,2} = q^j_{1,2}$, $j \in \{2, startup\}$, then firm 1 keeps market 1
3. Potential Startup has advantage in other market

   $\Rightarrow$ if $q^1_{2,2} = q^s_{2,2} > q^2_{2,2}$, then potential startup wins market 2

* Less strict assumption of splitting market shares does not change the qualitative analysis results

◀ decision rule

Firm 1's Innovation Problem in Period 1

$$V(q_{1,1}) = \max_{\{z_{1,1},\, x_{1,1}\}} \left\{ \begin{array}{l} \pi q_{1,1} - \widehat{\chi}(z_{1,1})^2 q_{1,1} - \widetilde{\chi}(x_{1,1})^2 q_{2,0} \\ \\ +(1-x_{2,1})(1-\tau)\Big[(1-z_{1,1})\pi' q_{1,1} + z_{1,1}\pi'\lambda q_{1,1}\Big] \\ \\ +(x_{2,1}+\tau - x_{2,1}\tau)\Big[(1-z_{1,1})\pi' q_{1,1}\, \mathcal{I}_{\{q_{1,1} \geq \eta q_{1,0}\}} \\ \qquad\qquad\qquad\qquad + z_{1,1}\pi'\, \lambda\, q_{1,1}\, \mathcal{I}_{\{\lambda q_{1,1} \geq \eta q_{1,0}\}}\Big] \\ \\ +x_{1,1}\Big[(1-\tau)\Big((1-z_{2,1})\, \pi'\, \eta\, q_{2,0}\, \mathcal{I}_{\{\eta q_{2,0} > q_{2,1}\}} \\ \qquad\qquad\qquad\qquad + z_{2,1}\, \pi'\, \eta\, q_{2,0}\, \mathcal{I}_{\{\eta q_{2,0} > \lambda q_{2,1}\}}\Big)\Big] \end{array} \right\}$$

◂ decision rule

Firm 1's Innovation Problem in Period 1

$$V(q_{1,1}) = \max_{\{z_{1,1},\, x_{1,1}\}} \left\{ \begin{array}{l} \pi q_{1,1} - \widehat{\chi}(z_{1,1})^2 q_{1,1} - \widetilde{\chi}(x_{1,1})^2 q_{2,0} \\ \\ +(1-x_{2,1})(1-\tau)\Big[(1-z_{1,1})\pi' q_{1,1} + z_{1,1}\pi'\lambda q_{1,1}\Big] \\ \\ +(x_{2,1}+\tau-x_{2,1}\tau)\Big[(1-z_{1,1})\pi' q_{1,1}\,\mathcal{I}_{\{q_{1,1}\geq \eta q_{1,0}\}} \\ \qquad\qquad\qquad + z_{1,1}\pi'\,\lambda\, q_{1,1}\,\mathcal{I}_{\{\lambda q_{1,1}\geq \eta q_{1,0}\}}\Big] \\ \\ +x_{1,1}\Big[(1-\tau)\Big((1-z_{2,1})\,\pi'\,\eta\, q_{2,0}\,\mathcal{I}_{\{\eta q_{2,0} > q_{2,1}\}} \\ \qquad\qquad\qquad + z_{2,1}\,\pi'\,\eta\, q_{2,0}\,\mathcal{I}_{\{\eta q_{2,0} > \lambda q_{2,1}\}}\Big)\Big] \end{array} \right\}$$

- Period 1 profit from market 1 net of innovation costs

decision rule

Firm 1's Innovation Problem in Period 1

$$V(q_{1,1}) = \max_{\{z_{1,1},\, x_{1,1}\}} \left\{ \begin{array}{l} \pi q_{1,1} - \widehat{\chi}(z_{1,1})^2 q_{1,1} - \widetilde{\chi}(x_{1,1})^2 q_{2,0} \\ \\ +(1-x_{2,1})(1-\tau)\Big[(1-z_{1,1})\pi' q_{1,1} + z_{1,1}\pi'\lambda q_{1,1}\Big] \\ \\ +(x_{2,1}+\tau-x_{2,1}\tau)\Big[(1-z_{1,1})\pi' q_{1,1}\,\mathcal{I}_{\{q_{1,1}\geq \eta q_{1,0}\}} \\ \qquad\qquad\qquad +z_{1,1}\pi'\,\lambda\, q_{1,1}\,\mathcal{I}_{\{\lambda q_{1,1}\geq \eta q_{1,0}\}}\Big] \\ \\ +x_{1,1}\Big[(1-\tau)\Big((1-z_{2,1})\,\pi'\,\eta\, q_{2,0}\,\mathcal{I}_{\{\eta q_{2,0} > q_{2,1}\}} \\ \qquad\qquad\qquad +z_{2,1}\,\pi'\,\eta\, q_{2,0}\,\mathcal{I}_{\{\eta q_{2,0} > \lambda q_{2,1}\}}\Big)\Big] \end{array} \right\}$$

- Expected profit from product market 1 when other two firms fail creative destruction

◀ decision rule

Firm 1's Innovation Problem in Period 1

$$V(q_{1,1}) = \max_{\{z_{1,1},\, x_{1,1}\}} \left\{ \begin{array}{l} \pi q_{1,1} - \widehat{\chi}(z_{1,1})^2 q_{1,1} - \widetilde{\chi}(x_{1,1})^2 q_{2,0} \\ \\ +(1-x_{2,1})(1-\tau)\Big[(1-z_{1,1})\pi' q_{1,1} + z_{1,1}\pi'\lambda q_{1,1}\Big] \\ \\ +(x_{2,1}+\tau-x_{2,1}\tau)\Big[(1-z_{1,1})\pi' q_{1,1}\, \mathcal{I}_{\{q_{1,1} \geq \eta q_{1,0}\}} \\ \qquad\qquad + z_{1,1}\pi'\, \lambda\, q_{1,1}\, \mathcal{I}_{\{\lambda q_{1,1} \geq \eta q_{1,0}\}}\Big] \\ \\ +x_{1,1}\Big[(1-\tau)\Big((1-z_{2,1})\, \pi'\, \eta\, q_{2,0}\, \mathcal{I}_{\{\eta q_{2,0} > q_{2,1}\}} \\ \qquad\qquad + z_{2,1}\, \pi'\, \eta\, q_{2,0}\, \mathcal{I}_{\{\eta q_{2,0} > \lambda q_{2,1}\}}\Big)\Big] \end{array} \right\}$$

- Expected profit from product market 1 when at least one outside firm succeeds creative destruction

◂ decision rule

Firm 1's Innovation Problem in Period 1

$$V(q_{1,1}) = \max_{\{z_{1,1},\, x_{1,1}\}} \left\{ \begin{array}{l} \pi q_{1,1} - \widehat{\chi}(z_{1,1})^2 q_{1,1} - \widetilde{\chi}(x_{1,1})^2 q_{2,0} \\ +(1-x_{2,1})(1-\tau)\Big[(1-z_{1,1})\pi' q_{1,1} + z_{1,1}\pi'\lambda q_{1,1}\Big] \\ +(x_{2,1}+\tau-x_{2,1}\tau)\Big[(1-z_{1,1})\pi' q_{1,1}\,\mathcal{I}_{\{q_{1,1} \geq \eta q_{1,0}\}} \\ \qquad\qquad +z_{1,1}\pi'\,\lambda\, q_{1,1}\,\mathcal{I}_{\{\lambda q_{1,1} \geq \eta q_{1,0}\}}\Big] \\ +x_{1,1}\Big[(1-\tau)\Big((1-z_{2,1})\,\pi'\,\eta\, q_{2,0}\,\mathcal{I}_{\{\eta q_{2,0} > q_{2,1}\}} \\ \qquad\qquad +z_{2,1}\,\pi'\,\eta\, q_{2,0}\,\mathcal{I}_{\{\eta q_{2,0} > \lambda q_{2,1}\}}\Big)\Big] \end{array} \right\}$$

- Expected profit from creative destruction when potential startup fails creative destruction

◂ decision rule

Proposition 1 (Market-Protection Effect)

For each $q_{1,1}$ and for $\eta > \lambda > 1$, we can order the own-innov. intensity as

$$z^*_{1,1}\Big|_{\frac{q_{1,1}}{q_{1,0}}=\lambda} > z^*_{1,1}\Big|_{\frac{q_{1,1}}{q_{1,0}}=\eta} > z^*_{1,1}\Big|_{\frac{q_{1,1}}{q_{1,0}}=1}$$

Furthermore,

$$\frac{\partial z^*_{1,1}}{\partial x_{1,1}}\Bigg|_{\frac{q_{1,1}}{q_{1,0}}=\lambda} > \frac{\partial z^*_{1,1}}{\partial x_{1,1}}\Bigg|_{\frac{q_{1,1}}{q_{1,0}}=\eta} = 0 > \frac{\partial z^*_{1,1}}{\partial x_{1,1}}\Bigg|_{\frac{q_{1,1}}{q_{1,0}}=1}$$

- Implication : Local technology gap in own market determines own-innov. intensity and responsiveness to competition

Main

Corollary 1

For the period 0 innovation intensity in market 1, $z_{1,0}$, we have

$$\frac{\partial z^*_{1,1}}{\partial z_{1,0}} > 0\ , \text{ and } \frac{\partial z^*_{1,1}}{\partial x_{1,1} \partial z_{1,0}} > 0\ .$$

- Implication 1 : Intensive innovation in previous period induces firms to do more own-innovation, and
- Implication 2 : incentivize firms to do more own-innovation when faced with higher product market competition

Main

Proposition 2

For each $q_{1,1}$ *and for* $\eta > \lambda > 1$*, we can order the creative destruction intensity as*

$$X^*_{1,1}\Big|_{\frac{q_{1,1}}{q_{1,0}}=1} \quad > \quad X^*_{1,1}\Big|_{\frac{q_{1,1}}{q_{1,0}}=\lambda} \quad > \quad X^*_{1,1}\Big|_{\frac{q_{1,1}}{q_{1,0}}=\eta} \; = \; 0$$

- Implication: Creative destruction intensity depends on local technology gap

  in target market

◂ Main

Corollary 2 (Technological-Barrier Effect)

For a given technology $q_{1,1}$ *and for the period 0 innovation intensity in market 1,* $z_{1,0}$*, we have*

$$\frac{\partial x^*_{1,1}}{\partial z_{1,0}} < 0 \, .$$

- Implication : Technology barrier built by past period innovation in the target market discourages firms' creative destruction

Main

Proposition 3 ((Ex-post) Schumpeterian Effect)

For the period 2 profit $\pi_{1,2}$, we have

$$\frac{\partial z_{1,1}^*}{\partial \pi_{1,2}} > 0 \text{ and } \frac{\partial x_{1,1}^*}{\partial \pi_{1,2}} > 0 \,.$$

Furthermore, for an anticipated creative destruction shock $x_{1,2}$ next period, we have

$$\frac{\partial z_{1,1}^*}{\partial x_{1,2}} < 0 \text{ and } \frac{\partial x_{1,1}^*}{\partial x_{1,2}} < 0 \,.$$

- Implication : Any factor changing expected future profits (e.g. export opportunity) affect firms' innovation decision

Main

Backward Citation Gap and Self-Citation Ratio

- $CitationGap_{ipct} = \alpha + \beta SelfCite_{ipct} + \delta_{it} + \delta_{ct} + \varepsilon_{ipct}$
  - $CitationGap_{ipct}$: average backward citation gap for the cited patents by patent p of firm i in CPC c at t
  - $SelfCite_{ipct}$: the self-citation ratio of patent p of firm i
  - δ_{it}: firm-year FE
  - δ_{ct}: CPC-year FE

Backward Citation Gap and Self-Citation Ratio

- $CitationGap_{ipct} = \alpha + \beta SelfCite_{ipct} + \delta_{it} + \delta_{ct} + \varepsilon_{ipct}$
  - $CitationGap_{ipct}$: average backward citation gap for the cited patents by patent p of firm i in CPC c at t
  - $SelfCite_{ipct}$: the self-citation ratio of patent p of firm i
  - δ_{it}: firm-year FE
  - δ_{ct}: CPC-year FE

	Citation gaps	Citation gaps	Citation gaps
Self-citation ratio	-2.290***	-2.450***	-2.592***
	(0.018)	(0.018)	(0.020)
Observations	728,721	728,721	728,721
Fixed effects	none	ct	it, ct

Main

Robustness Test of Learning Predictions

	Citation gaps	Citation gaps	Citation gaps	Citation gaps	Citation gaps
Self-citation ratio	-0.781***	-2.575***	-2.386***	-2.379***	-1.972***
	(0.040)	(0.020)	(0.027)	(0.027)	(0.024)
CPC class number			0.121***	0.125***	
			(0.002)	(0.002)	
Std of citation gaps					0.549***
					(0.018)
Observations	697,968	728,299	504,607	504,607	670,300
Fixed effects	*it*, *ct*	*it*, *ct*	*it*, *ct*	*it*, *ct*	*it*, *ct*
Sample/Controls	No Self-citation	Non-expired only	CPC#	CPC# (excl. own)	std.

Main

Quality of Own-Innovation vs. Creative Destruction

- $Quality_{ipct} = \alpha + \beta_1 SelfCite_{ipct} + \beta_2 X_{it-1} + \delta_{ct} + \varepsilon_{ipct}$
  - $Quality_{ipct}$: log market value (M-value) or # forward citations (S-value) for patent p in cpc c by firm i at t
  - $SelfCite_{ipct}$: self-citation ratio of firm i's patent p
  - X_{it-1}: firm size at $t-1$
  - δ_{ct}: cpc-year fixed effect

Quality of Own-Innovation vs. Creative Destruction

- $Quality_{ipct} = \alpha + \beta_1 SelfCite_{ipct} + \beta_2 X_{it-1} + \delta_{ct} + \varepsilon_{ipct}$
  - $Quality_{ipct}$: log market value (M-value) or # forward citations (S-value) for patent p in cpc c by firm i at t
  - $SelfCite_{ipct}$: self-citation ratio of firm i's patent p
  - X_{it-1}: firm size at $t-1$
  - δ_{ct}: cpc-year fixed effect

	M-value	M-value	S-value	S-value
Self-citation	-0.289***	-0.027***	-0.082***	-0.047***
	(0.006)	(0.005)	(0.008)	(0.008)
Market cap$_{-1}$	0.431***	0.289***	-0.025***	-0.043***
	(0.001)	(0.003)	(0.001)	(0.005)
Observations	360,750	360,750	360,750	360,750
Fixed effects	ct	i, ct	ct	i, ct

Main

Robustness Test of Heterogeneous Outcome

	ΔTFPR	#prod. add	ΔHHI	ΔTFPR	#prod. add	ΔHHI
#patents (self-cite=0)	0.118**	0.358**	-0.124**	0.129**	0.354***	-0.120**
	(0.055)	(0.085)	(0.055)	(0.052)	(0.081)	(0.052)
#patents (self-cite>0.10)	-0.027	-0.274***	0.134**	-0.055	-0.317***	0.152**
	(0.053)	(0.102)	(0.063)	(0.056)	(0.118)	(0.067)
Observations	5,700	5,700	5,700	5,700	5,700	5,700
Fixed effects	*jt*	*jt*	*jt*	*jt*	*jt*	*jt*
Own-innov. cutoffs	0%	0%	0%	10%	10%	10%

Main

Real Effect of Two Types of Innovation

- Differential effect of own-innov. vs. creative dest. on various firm-level outcomes
- Extension of Akcigit and Kerr (2018) exercise

$$Y_{ijt+5} = \beta_1 \log(Patent)_{ijt} + \beta_2 Self\text{-}Citation_{ijt} + \mathbf{X}_{ijt}\gamma_1 + \delta_{jt+5} + \varepsilon_{ijt+5}$$

- Y_{ijt+5} : i) DHS growth of firm emp. growth, ii) log nb. of industries added, and iii) log nb. of products (5-digit SIC) added from t to $t+5$
- $\log(Patent)_{ijt}$: log of citation-adj. nb. of pat., mean: 1.284 (=3.61 patents), stdev: 1.125
- $Self\text{-}Citation_{ijt}$: citation-wgted. avg. self-citation ratios, mean: 0.050, stdev: 0.101
- Sample periods: 1982-1987, 1992-1997 (two non-overlapping 5yr growths, Census years)
- Regression is unweighted, s.e. clustered on firm

Main

Real Effect of Two Types of Innovation Results

	LBD firms		CMF firms
	ΔEmployment	Log nb. of industries added	Log nb. of products added
	(1)	(2)	(3)
Log nb. of patents	0.036***	0.102***	0.083***
	(0.010)	(0.011)	(0.013)
Avg. self-citation	-0.256**	-0.158**	-0.286***
	(0.109)	(0.079)	(0.093)
Log payroll	-0.027***	0.113***	0.149***
	(0.008)	(0.006)	(0.005)
Firm age	-0.004**	0.002	-0.002
	(0.002)	(0.002)	(0.002)
Innovation intensity	-0.004	-0.006**	0.009
	(0.003)	(0.003)	(0.008)
Observations	5,400	5,400	5,700
Fixed effects	*jp*	*jp*	*jp*

- Positive relationship b/w outcome variables and number of patents
- Negative relationship b/w outcome variables and own-innovation
- mean log patent = 1.284 (=3.61 patents)

Measure for Trade Shock

- Foreign competition shocks from China: the removal of industry-level NTR gap
  - U.S. has two basic tariff schedules:
    - Normal Trade Relations (NTR) rates for WTO members (4%)
    - Non-NTR rates for non-market economy (37%) set by Smoot-Hawley (1930)
  - China was granted temp. NTR status from 1980, requiring annual reapproval by Congress

Measure for Trade Shock

- Foreign competition shocks from China: the removal of industry-level NTR gap
  - U.S. has two basic tariff schedules:
    - Normal Trade Relations (NTR) rates for WTO members (4%)
    - Non-NTR rates for non-market economy (37%) set by Smoot-Hawley (1930)
  - China was granted temp. NTR status from 1980, requiring annual reapproval by Congress
  - **Annual reapproval ⇒ uncertainty about ↑↑ tariff rate, deterring CN export to the U.S.**
  - Use the difference b/w the two rates as a proxy for the effect of TPU in each industry

$$\text{NTR Gap}_j = \text{Non-NTR Rate}_j - \text{NTR Rate}_j$$

    - Most variations come from Non-NTR rate ⇒ exogenous from firm outcomes near 2000
    - First order approx. of any TPU measures with (-) in NTR rates and (+) in non-NTR rates
  - **CN was granted perm. NTR status after entering WTO (exogenous sharp drop in TPU)**

Main

Effect of TPU removal on U.S. imports from CN

	ΔCN imp	ΔCN imp
	HS8-level	NAICS6-level
	(1)	(1)
NTR gap	0.209***	0.594**
	(0.059)	(0.243)
ΔNTR rate	-0.043***	-0.204**
	(0.015)	(0.080)
ΔTransport cost	-0.791***	-0.491
	(0.194)	(0.766)
Obsevations	10,089	490

Main

Summary Statistics

	All patenting firms	Regression sample
Average number of patents	6.15	8.86
	(19.46)	(24.10)
Average self-citation rate	0.0434	0.0540
	(0.0899)	(0.0941)
Innovation intensity	0.055	0.093
	(0.25)	(0.33)
Number of industries operating	2.34	5.43
	(3.67)	(6.94)
Employment	511.7	1988.0
	(1869.0)	(3835.0)
Patent stock	6.45	35.22
	(26.61)	(64.37)
Employment growth	0.07	0.06
	(0.60)	(0.40)
Firm age	12.33	15.65
	(6.76)	(9.42)
7yr patent growth		-0.854
		(1.312)
7yr self-citation ratio growth		0.356
		(1.322)
Number of firms	26,500	3,100

Main

Trade Shocks

	NTR gap	Dnstream NTR gap	Upstream NTR gap	NTR rate	Non-NTR rate	Export shock
Mean	0.291	0.138	0.203	0.027	0.303	1.127
(Std. dev.)	(0.127)	(0.060)	(0.073)	(0.022)	(0.134)	(0.970)
cov(, NTR gap)		0.485	0.434	0.412	0.969	0.214
cov(, Up. NTR gap)		0.204				

	NTR gap, unweighted	NTR gap, main industry
Mean	0.333	0.336
(Std. dev.)	(0.107)	(0.116)
cov(, NTR gap)	0.78	0.86
cov(, NTR gap, main industry)	0.906	

Main

Effect of Competition on Creative Destruction (Product Added)

	Δproducts added
NTR gap × Post	-0.239***
	(0.068)
Observations	497,000
Fixed effects	j, p
Controls	baseline

- Firms add **less** new products (**reduce creative destruction**) under competitive pressure

Main

Robustness Test

- Parallel pre-trend/placebo test: satisfied ▸ Results
- Propagation through I-O linkage: results not statistically significant ▸ Results
- Industry-level NTR measures ▸ Results
- Correcting potential selection bias with inverse propensity scores ▸ Results
- Additional firm-level controls for cumulative number of patents or trade status ▸ Results ▸ Results
- Controlling potential age/size effects of innovation intensity ▸ Results
- Alternative technological barrier and innovation measures ▸ Results
- Industry-level controls (skill, capital intensities, industry #) ▸ Results
- Cluster standard errors on firms ▸ Results

◂ Main

Effect of Competition on Product Concentration

	Δproduct HHI	Δproduct HHI
	(1)	(2)
NTR gap × Post	-0.002	-0.019
	(0.042)	(0.012)
× tech gap		0.262**
		(0.116)
Observations	497,000	497,000
Fixed effects	j, p	j, p
Controls	baseline	baseline

- Firms w/ **tech.advantage increase product concentration** under competitive pressure

Main

Market-Protection Effect (w/ and w/o ctrls)

	ΔPatents	ΔPatents	ΔSelf-cite	ΔSelf-cite
	(1)	(2)	(3)	(4)
NTR gap × Post	0.238	0.071	-0.075	-0.062
	(0.237)	(0.283)	(0.257)	(0.291)
× Innovation intensity	0.077	-0.054	0.732**	0.795***
	(0.231)	(0.242)	(0.299)	(0.277)
NTR gap	-2.206***	0.418	1.101***	-0.005
	(0.375)	(0.412)	(0.315)	(0.394)
× Innovation intensity	-0.226	-0.161	-0.198	-0.390
	(0.158)	(0.184)	(0.231)	(0.236)
Post × Innovation intensity	-0.053	0.040	-0.179*	-0.202**
	(0.070)	(0.079)	(0.095)	(0.087)
Innovation intensity	0.080*	0.029	0.059	0.088
	(0.048)	(0.051)	(0.070)	(0.068)
Past 5yr Δpat in own tech.		0.164*		0.265***
		(0.084)		(0.083)
Log employment		0.161***		-0.025**
		(0.011)		(0.012)
Firm age		-0.005**		-0.011***
		(0.002)		(0.002)
NTR rate		-2.619		1.024
		(1.683)		(2.224)
× Innovation intensity		0.690		0.625
		(0.531)		(0.501)
Observations	6,500	6,500	6,500	6,500
Fixed effects	j, p	j, p	j, p	j, p
Controls	no	baseline	no	baseline

Parallel Pre-Trend Test

	Overall	Market-protection	Overall	Market-protection
	ΔPatents	ΔPatents	ΔSelf-cite	ΔSelf-cite
	(1)	(2)	(3)	(4)
NTR gap	-0.397	-0.380	-0.554	-0.546
	(0.487)	(0.488)	(0.403)	(0.402)
× Innovation intensity		-0.195		-0.058
		(0.162)		(0.395)
NTR gap × $\mathcal{I}_{\{1992\}}$	0.523	0.500	0.252	0.259
	(0.355)	(0.362)	(0.294)	(0.290)
× Innovation intensity		0.092		-0.113
		(0.243)		(0.491)
Observations	5,000	5,000	5,000	5,000
Fixed effects	j, p	j, p	j, p	j, p
Controls	baseline	baseline	baseline	baseline

- Key identifying assumption: ctrl and treatment groups have similar trends before treatment
- Dependent variables are in growth rates $\Rightarrow$ coefficients on NTR gap shows trend differential

  $\Rightarrow$ Run the baseline specification using two pre-2000 7yr periods (1984-1991, 1992-2000)

Main

Competition Effect with I-O Linkage

	Overall	Market-protection	Overall	Market-protection
	ΔPatents	ΔPatents	ΔSelf-cite	ΔSelf-cite
	(1)	(2)	(3)	(4)
NTR gap × Post	-0.111	-0.111	-0.296	-0.424
	(0.331)	(0.342)	(0.356)	(0.355)
× Innovation intensity		-0.001		0.824***
		(0.337)		(0.288)
Observations	6,500	6,500	6,500	6,500
Fixed effects	j, p	j, p	j, p	j, p
Controls	baseline+IO	baseline+IO	baseline+IO	baseline+IO

Main

Industry-level NTR Gap

	Overall	Market-protection	Overall	Market-protection
	ΔPatents	ΔPatents	ΔSelf-cite	ΔSelf-cite
	(1)	(2)	(3)	(4)
NTR gap × Post	0.016	0.011	0.005	-0.001
	(0.249)	(0.249)	(0.261)	(0.261)
× Innovation intensity		-0.032		0.760***
		(0.229)		(0.272)
Observations	6,500	6,500	6,500	6,500
Fixed effects	j, p	j, p	j, p	j, p
Controls	baseline	baseline	baseline	baseline
Weights for tariffs	major industry	major industry	major industry	major industry

◂ Main

Weighted Regression with Inverse Propensity Scores

	Overall	Market-protection	Overall	Market-protection
	ΔPatents	ΔPatents	ΔSelf-cite	ΔSelf-cite
	(1)	(2)	(3)	(4)
NTR gap × Post	0.003	0.039	-0.394	-0.603
	(0.475)	(0.484)	(0.509)	(0.512)
× Innovation intensity		-0.045		0.893***
		(0.282)		(0.294)
Observations	6,500	6,500	6,500	6,500
Fixed effects	j, p	j, p	j, p	j, p
Controls	baseline	baseline	baseline	baseline
Regression weights	inv. propens.	inv. propens.	inv. propens.	inv. propens.

Main

Controlling for the cumulative number of patents

	ΔPatents	ΔPatents	ΔSelf-cite	ΔSelf-cite
	(1)	(2)	(3)	(4)
NTR gap × Post	0.074	0.076	0.030	-0.078
	(0.276)	(0.283)	(0.291)	(0.290)
× Innovation intensity		-0.055		0.798***
		(0.242)		(0.278)
Observations	6,500	6,500	6,500	6,500
Fixed effects	j, p	j, p	j, p	j, p
Controls	baseline+cum. patent #	baseline+cum. patent #	baseline+cum. patent #	baseline+cum. patent #

Main

Controlling for trade status

	ΔPatents	ΔPatents	ΔSelf-cite	ΔSelf-cite
	(1)	(2)	(3)	(4)
NTR gap × Post	0.067	0.074	0.166	0.063
	(0.272)	(0.280)	(0.287)	(0.285)
× Innovation intensity		-0.029		0.777***
		(0.231)		(0.268)
Observations	6,500	6,500	6,500	6,500
Fixed effects	j, p	j, p	j, p	j, p
Controls	baseline+import,export	baseline+import,export	baseline+import,export	baseline+import,export

Main

CONTROLLING FOR AGE/SIZE EFFECTS OF INNOVATION INTENSITY

	ΔPatents	ΔPatents	ΔSelf-cite	ΔSelf-cite
	(1)	(2)	(3)	(4)
NTR gap × Post	-0.447	-0.342	0.805	0.292
	(0.645)	(0.691)	(0.668)	(0.641)
× Innovation intensity		-0.026		0.826***
		(0.239)		(0.284)
Observations	6,500	6,500	6,500	6,500
Fixed effects	j, p	j, p	j, p	j, p
Controls	baseline	baseline	baseline	baseline
	+age,size x innovation intensity	+age,size x innovation intensity	+age,size x innovation intensity	+age,size x innovation

Main

ALTERNATIVE INNOVATION & TECHNOLOGICAL BARRIER MEASURES

	Δproducts added	Δown-innov. patents (self-cit.>0)	Δown-innov. patents (self-cit.>0)	Δown-innov. patents (self-cit.>10)	Δown-innov. p (self-cit.>1
	(1)	(2)	(3)	(4)	(5)
NTR gap × Post	-0.231***	0.007	0.001	0.005	-0.008
	(0.067)	(0.004)	(0.004)	(0.004)	(0.005)
× Inverse labor productivity gap			0.100***		0.206***
			(0.045)		(0.040)
Observations	6,500	6,500	6,500	6,500	6,500
Fixed effects	j, p	j, p	j, p	j, p	j, p
Controls	baseline	baseline	baseline	baseline	baseline

◂ Main

Alternative innovation & technological barrier measures

	Δproducts added	Δown-innov. patents (self-cit.>0)	Δown-innov. patents (self-cit.>0)	Δown-innov. patents (self-cit.>10)	Δown-innov. patents (self-cit.>10)
	(1)	(2)	(3)	(4)	(5)
NTR gap × Post	-0.218***	0.007	0.004	-0.004	-0.008
	(0.063)	(0.004)	(0.004)	(0.005)	(0.005)
× Inverse tfpr gap			0.102***		0.128***
			(0.030)		(0.028)
Observations	6,500	6,500	6,500	6,500	6,500
Fixed effects	j, p	j, p	j, p	j, p	j, p
Controls	baseline	baseline	baseline	baseline	baseline

Main

Controlling for industry characteristics

	ΔPatents	ΔPatents	ΔSelf-cite	ΔSelf-cite
	(1)	(2)	(3)	(4)
NTR gap × Post	0.075	0.081	0.149	0.042
	(0.272)	(0.279)	(0.288)	(0.285)
× Innovation intensity		-0.055		0.787***
		(0.240)		(0.279)
Observations	6,500	6,500	6,500	6,500
Fixed effects	j, p	j, p	j, p	j, p
Controls	baseline+industry#, skill,capital intensities	baseline+industry#, skill,capital intensities	baseline+industry#, skill,capital intensities	baseline+industry#, skill,capital intensities

◂ Main

Standard Errors Clustered at Firm Level

	Overall	Market-protection	Overall	Market-protection
	ΔPatents	ΔPatents	ΔSelf-cite	ΔSelf-cite
	(1)	(2)	(3)	(4)
NTR gap × Post	0.067	0.071	0.045	-0.062
	(0.287)	(0.290)	(0.308)	(0.312)
× Innovation intensity		-0.054		0.795***
		(0.245)		(0.277)
Observations	6,500	6,500	6,500	6,500
Fixed effects	j, p	j, p	j, p	j, p
Controls	baseline	baseline	baseline	baseline
se. cluster	firmid	firmid	firmid	firmid

◂ Main