Heterogeneous Innovations and Growth under Imperfect Technology Spillovers

Karam Jo
Penn State

Seula Kim
Penn State

Conference in Honor of John C. Haltiwanger

November 7, 2025

DISCLAIMER: Any views expressed are those of the authors and not those of Korea Development Institute and the U.S. Census Bureau. The Census Bureau's Disclosure Review Board and Disclosure Avoidance Officers have reviewed this information product for unauthorized disclosure of confidential information and have approved the disclosure avoidance practices applied to this release. This research was performed at a Federal Statistical Research Data Center under FSRDC Project Number 2095 (CBDRB-FY24-0073, CBDRB-FY24-0311).

Motivation

- **Firm innovations manifest in diverse forms with different features**:
    - Some build on own existing technologies vs. others require learning new ones
    - Heterogeneous innovations impact firm performance and economic growth differently
    - Firms have varying incentives to use different types of innovations

      (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**:
  - Some build on own existing technologies vs. others require learning new ones
  - Heterogeneous innovations impact firm performance and economic growth differently
  - Firms have varying incentives to use different types of innovations

    (Gilbert 2006; Akcigit and Kerr 2018; Garcia-Macia et al. 2019; Peters 2020; Argente et al. 2024)
- **Learning technology takes time and can affect firm innovation decisions**:
  - Firm innovation involves learning about existing technologies (Lucas and Moll 2014)
  - In reality, learning takes time: avg. backward citation duration $\simeq 5.55$ yr in patent data
  - Learning frictions can create strategic incentives for firms, impacting innovation composition and growth

Research Questions

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

> Q. How do firms use different innovations when learning technology takes time?
>
> Q. How does this process affect the aggregate economy?

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. learning 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. learning 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. learning 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. learning 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 use innovation strategically and build technological barriers to defend, creating feedback effects to other firms

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. learning 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 use innovation strategically and build technological barriers to defend, creating feedback effects to other firms
- **Empiric:**
  - Firm-level data from the US Census Bureau integ. w/ USPTO patent db.
  - Own-innovation vs. Creative destruction using self-citation ratio
  - Learning time measured by backward citation gaps
  - 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

⇒ ★ Characterize strategic interactions among different types of innovation and feedback effects

- **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

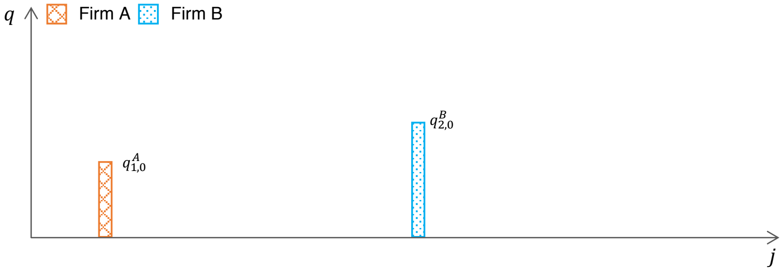
⇒ ★ Uncover an underlying endogenous force and mechanism behind the decreasing technology diffusion as a consequence of the strategic innovation choice of firms under learning frictions

- **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

⇒ ★ Assess the effect of competition through innovation composition by multi-product firm choices and reconcile the prior results

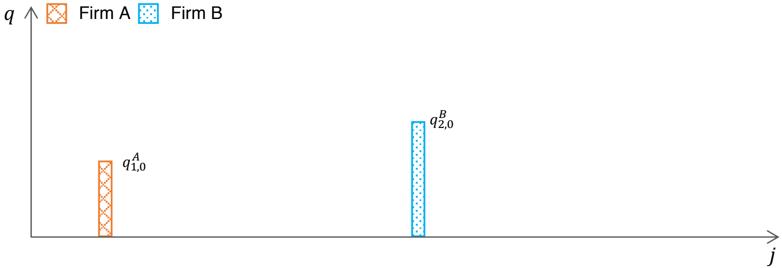
Mechanism Illustration

Two-Firm Two-Product Innovation Example



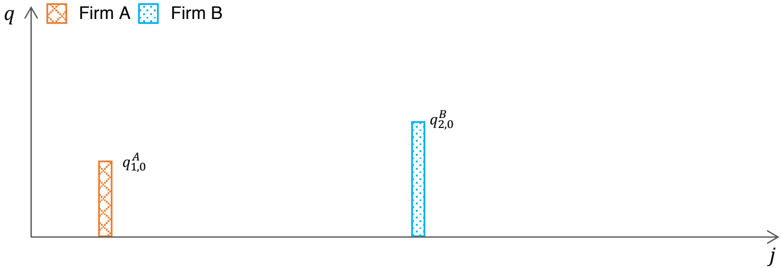
- Firm A owns product 1, firm B owns product 2
- Height of bar: product quality (technology) q (logged)
- Successful innovation improves product quality q (realized next period)
- Firms do two types of innovation: Own-innovation/Creative destruction

Own-Innovation (period 0)



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

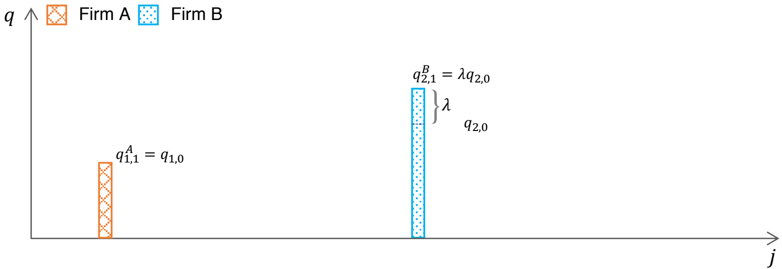
Own-Innovation (period 0)



- 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 $\lambda > 1$

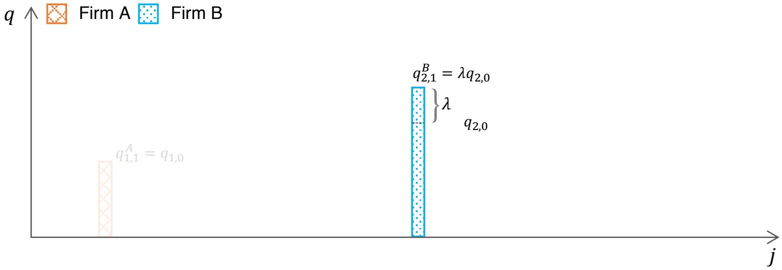
$$q_{j,1} = \begin{cases} q_{j,0} & \text{w/ prob. } 1 - z_{j,0} \\ \lambda q_{j,0} & \text{w/ prob. } z_{j,0} \end{cases}$$

Own-Innovation (period 1)



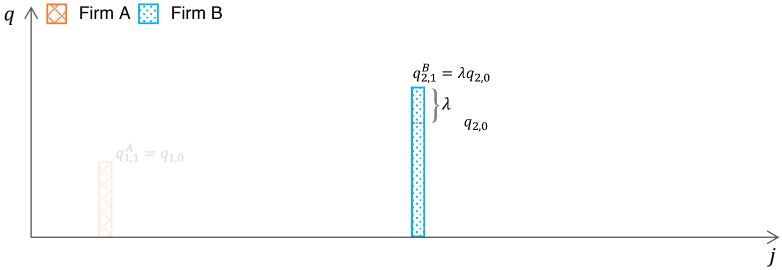
- We are in period 1 now
- Assume firm A fails while firm B succeeds in own-innovation

Creative Destruction (period 1)



* Now, let's allow creative destruction

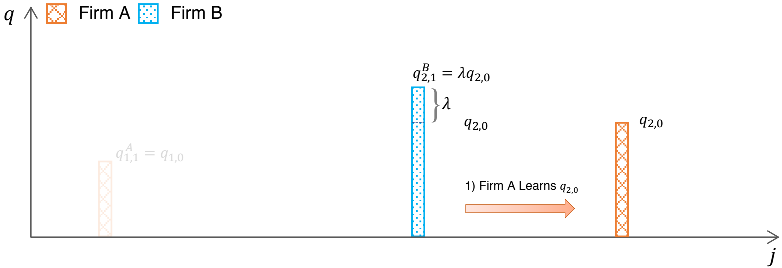
Creative Destruction (period 1)



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

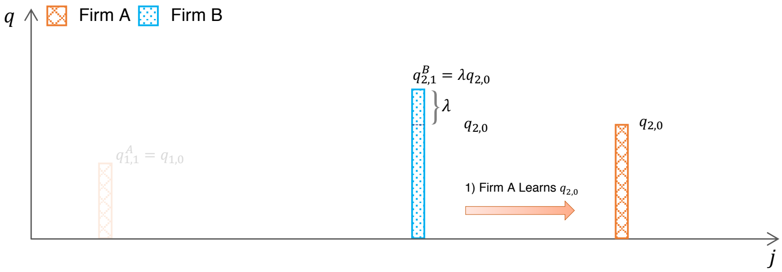
$\Longrightarrow$ **Needs to learn** firm B's technology and get higher q_2

Creative Destruction (period 1)



- But, learning takes time ▸ Detail

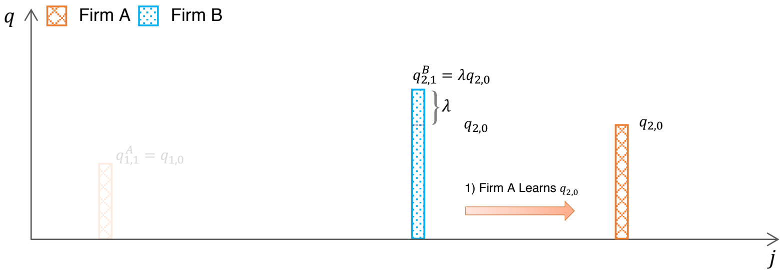
Creative Destruction (period 1)



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

  Creative destruction builds on past-period technology of incumbent

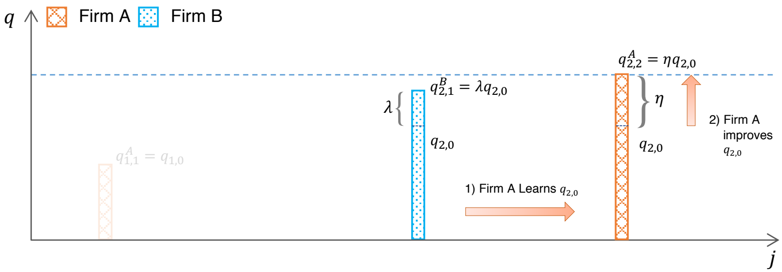
Creative Destruction (period 1)



- 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

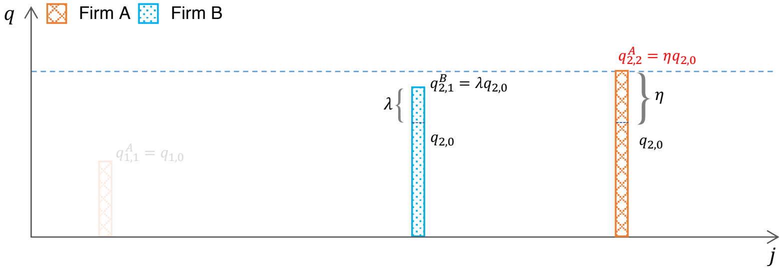
Creative Destruction (period 1)



- As before, R&D investment ($R^{ex}_{2,1}$) $\Rightarrow$ 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

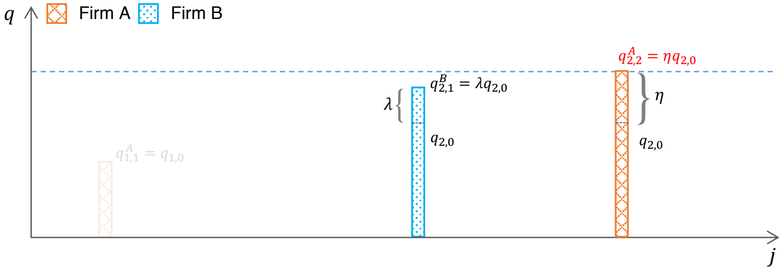
$$q^A_{2,2} = \begin{cases} q_{2,0} & \text{w/ prob. } 1 - x_{2,1} \\ \eta q_{2,0} & \text{w/ prob. } x_{2,1} \end{cases}$$

Creative Destruction (period 2)



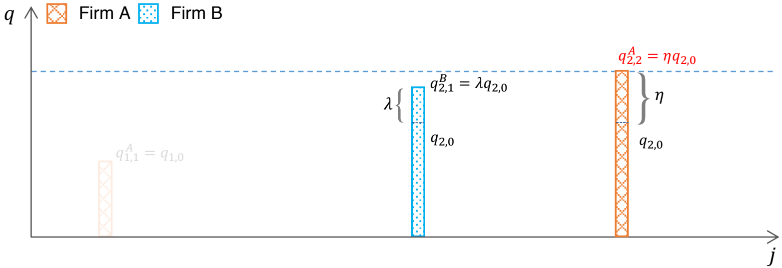
- We are in period 2
- Let's assume firm A made successful creative destruction: $q^A_{2,2} > q^B_{2,1}$

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?

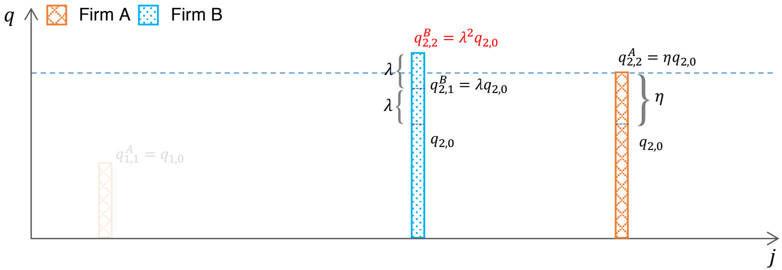
Creative Destruction (period 2)



- 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

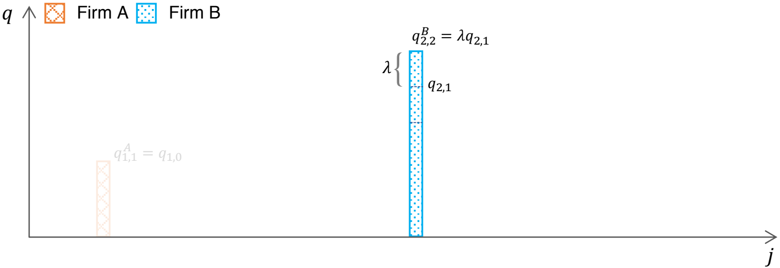
Market Protection (period 2)



- **Assumption:**

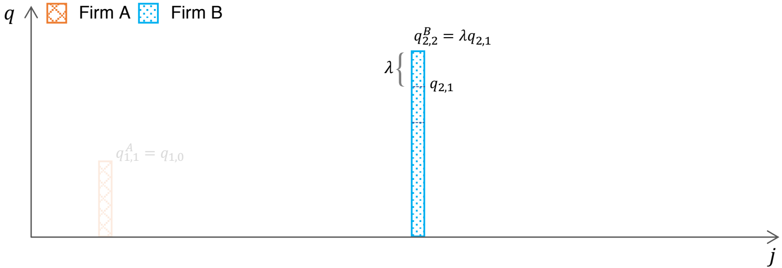
  Improvement through own-innovation is high enough that $\lambda^2 > \eta$

Market Protection (period 2)



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

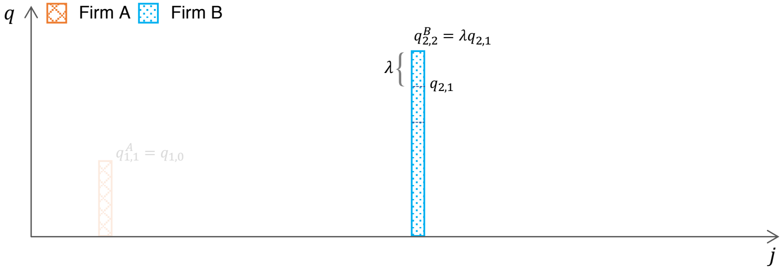
Market Protection (period 2)



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

And this can deter the creative destruction by firm A "endogenously"

Market Protection (period 2)



★ Implication: firm B can use tech. advantage accumulated b/w period 0 and 1 to protect its market
And this can deter the creative destruction by firm A "endogenously"

- If firms do not have enough tech. advantage, they won't be able to protect their markets (firm A)

▸ More

Key Findings

Decision Rules

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,

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

- Local technology gap determines own-innov. intensity and responsiveness to competition
- If $\exists$ tech. advantage of product owners $\rightarrow$ own-innovation $\uparrow$ when competitive pressure $\uparrow$

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

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

Key Findings

Decision Rules

Proposition 2 (Technology Barrier Effect)

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

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

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

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

- Creative destruction intensity depends on local technology gap in target markets
- Higher tech. barriers (w/ intensive own-innovation) dampen creative destruction

Extension and Aggregate Implications

- Our full-fledged model has all these features, allowing quantitative analysis ▸ Full-fledged
- Innovation composition matters for the aggregate level of innovation and growth (counterfactual analysis with increased competition) ▸ Calibration ▸ US ▸ Non US
- Learning time also matters for firm incentives and aggregate outcomes (extension w/ stochastic learning time) ▸ Extension

Empirics

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

  ▶ Summary ▶ Figure

  - **Backward citation gap**: the gap b/w a patent's application year and the publication years of the patents it cites (Jaffe et al. 1993, Hegde et al. 2023) $\Rightarrow$ Use average or minimum for each citing patent

Main Measures (cont'd)

- 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)

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

- Use **NTR Gap**$_{\mathbf{j}}$ measured in 1999 (a year before the US gov. granted Permanent-NTR status to China)

Heterogeneity in Firm Innovation

Learning Time: Own-Innov vs. Creative Destruction

▸ Figure ▸ Robustness

- $CitationGap_{ipct} = \alpha + \beta SelfCite_{ipct} + \delta_i + \delta_{ct} + \varepsilon_{ipct}$
  - $CitationGap_{ipct}$: avg. or min. 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_i: firm FE; δ_{ct}: cpc-year FE

Learning Time: Own-Innov vs. Creative Destruction

▸ Figure ▸ Robustness

- $CitationGap_{ipct} = \alpha + \beta SelfCite_{ipct} + \delta_i + \delta_{ct} + \varepsilon_{ipct}$
  - $CitationGap_{ipct}$: avg. or min. 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_i: firm FE; δ_{ct}: cpc-year FE

	Citation gaps (average)	Citation gaps (average)	Citation gaps (average)	Citation gaps (minimum)	Citation gaps (minimum)	Citation gaps (minimum)
Self-citation ratio	-1.946***	-1.992***	-2.080***	-0.770***	-0.897***	-1.013***
	(0.015)	(0.015)	(0.016)	(0.013)	(0.013)	(0.015)
Observations	817,764	817,736	775,652	817,764	817,736	775,652
Fixed effects	none	ct	i, ct	none	ct	i, ct

Learning Time: Own-Innov vs. Creative Destruction

▸ Figure ▸ Robustness

- $CitationGap_{ipct} = \alpha + \beta SelfCite_{ipct} + \delta_i + \delta_{ct} + \varepsilon_{ipct}$
  - $CitationGap_{ipct}$: avg. or min. 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_i: firm FE; δ_{ct}: cpc-year FE

	Citation gaps (average)	Citation gaps (average)	Citation gaps (average)	Citation gaps (minimum)	Citation gaps (minimum)	Citation gaps (minimum)
Self-citation ratio	-1.946***	-1.992***	-2.080***	-0.770***	-0.897***	-1.013***
	(0.015)	(0.015)	(0.016)	(0.013)	(0.013)	(0.015)
Observations	817,764	817,736	775,652	817,764	817,736	775,652
Fixed effects	none	ct	i, ct	none	ct	i, ct

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

Quality Improvement: Own-Innov vs. Creative Destruction

- $Quality_{ipct} = \alpha + \beta_1 SelfCite_{ipct} + \beta_2 X_{it-1} + \delta_i + \delta_{ct} + \varepsilon_{ipct}$
  - $Quality_{ipct}$: 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

Quality Improvement: Own-Innov vs. Creative Destruction

- $Quality_{ipct} = \alpha + \beta_1 SelfCite_{ipct} + \beta_2 X_{it-1} + \delta_i + \delta_{ct} + \varepsilon_{ipct}$
  - $Quality_{ipct}$: 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

Quality Improvement: Own-Innov vs. Creative Destruction

- $Quality_{ipct} = \alpha + \beta_1 SelfCite_{ipct} + \beta_2 X_{it-1} + \delta_i + \delta_{ct} + \varepsilon_{ipct}$
  - $Quality_{ipct}$: 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

Economic Outcome: Own-Innov vs. Creative Destruction

▸ Robustness

- $\Delta Y_{ijt+5} = \beta_1 Pat_{ijt} + \beta_2 Self_{ijt} + \mathbf{X}_{ijt}\gamma_1 + \delta_{jt+5} + \varepsilon_{ijt+5}$
  - Y_{ijt+5}: 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

Economic Outcome: Own-Innov vs. Creative Destruction

▸ Robustness

- $\Delta Y_{ijt+5} = \beta_1 Pat_{ijt} + \beta_2 Self_{ijt} + \mathbf{X}_{ijt}\gamma_1 + \delta_{jt+5} + \varepsilon_{ijt+5}$
  - Y_{ijt+5}: 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*

Economic Outcome: Own-Innov vs. Creative Destruction

▸ Robustness

- $\Delta Y_{ijt+5} = \beta_1 Pat_{ijt} + \beta_2 Self_{ijt} + \mathbf{X}_{ijt}\gamma_1 + \delta_{jt+5} + \varepsilon_{ijt+5}$
  - Y_{ijt+5}: 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 and Tech Barrier Effects

Market-Protection Effect

▸ Summary ▸ Trade shocks

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

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

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

  - 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 ▸ 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

- 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 Trade shocks

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

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

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

  - 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 $p0$
  - $\mathrm{X}_{ijp0}, \mathrm{X}_{jp0}$: 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 ▸ Trade shocks

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

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

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

  - 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 $p0$
  - $\mathrm{X}_{ijp0}, \mathrm{X}_{jp0}$: 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 → 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 → 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 → 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 p5 or p10 of the inverse of firm-level TFPR gap from the frontier in industry j at t (i.e., the skewness of TFPR dist.)

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 p5 or p10 of the inverse of firm-level TFPR gap from the frontier in industry j at t (i.e., the skewness of TFPR dist.)

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

Quantitative Analysis

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, $\Delta_j = \frac{\text{current period technology}}{\text{past period technology}}$

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%

- Suppose another (hypothetical) economy with different innovation cost structure from US ($\tilde{\chi} \times 80$)

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%

- Suppose another (hypothetical) economy with different innovation cost structure from US ($\tilde{\chi} \times 80$)
- 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%

- Suppose another (hypothetical) economy with different innovation cost structure from US ($\tilde{\chi} \times 80$)
- 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%

- Suppose another (hypothetical) economy with different innovation cost structure from US ($\tilde{\chi} \times 80$)
- 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

Concluding Remarks

Concluding Remarks

- Introduce imperfect technology spillover (learning) to growth model
- Firms can use diff. types of innovation to survive increased competition
- ★ Learning allows incumbents to increase own-innov. and build technological barriers
- ★ Creative destruction drops and lead to decline in firm entry (feedback effects)

$\Longrightarrow$ Firm innovation choices change innovation composition

- ★ Such innovation composition changes matter for aggregate growth
- Extension in progress: interaction with changes in learning time and labor market conditions

THANK YOU! ☺

karamjo@psu.edu

seulakim@psu.edu

Appendix

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

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

◂ decision rule

Firm 1's Innovation Problem in Period 1

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

- Period 1 profit from market 1 net of innovation costs

decision rule

Firm 1's Innovation Problem in Period 1

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

- 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

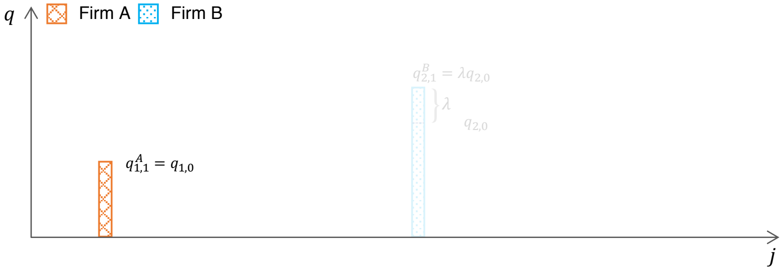
Firm 1's Innovation Problem in Period 1

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

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

◂ decision rule

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

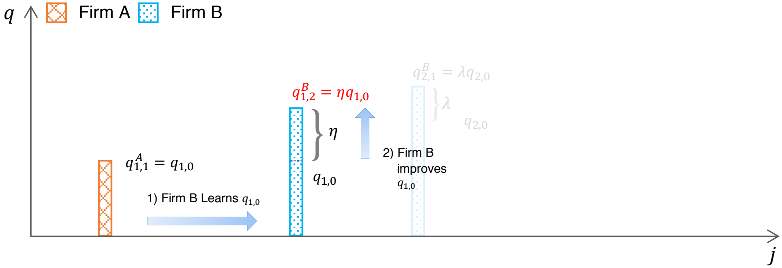


- Now, going back to period 1
- Recall that firm A had no successful innovation b/w period 0 and 1

$\Longrightarrow$ No tech. advantage in its own mkt. 1

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

Main

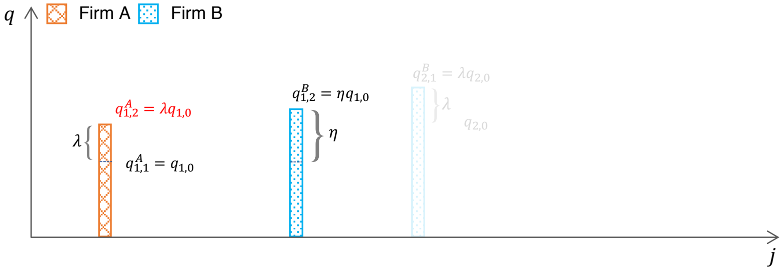


- Suppose firm B conducts creative destruction to target prod mkt. 1

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

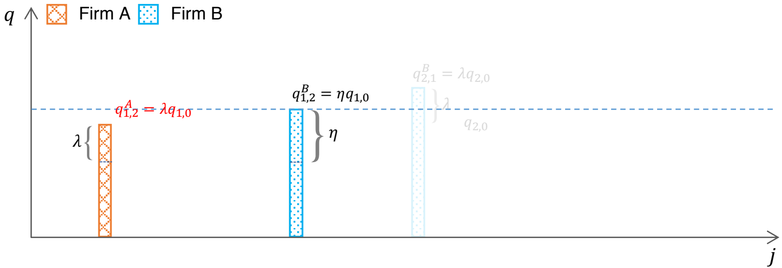
Market Protection w/o Tech. Advantage (period 1)

Main



- 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)

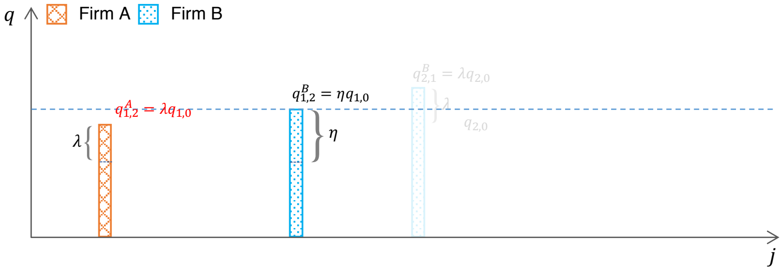


- Let's say both firm A and B succeed innovation. But $q^B_{1,2} > q^A_{1,2}$
- Firm B successfully take over prod. mkt. 1 from firm A (firm A fails to protect it even w/ successful own-innov.)

$\Longrightarrow$ Why? firm A does not have tech. advantage accumulated

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

Main



- Let's say both firm A and B succeed innovation. But $q^B_{1,2} > q^A_{1,2}$
- Firm B successfully take over prod. mkt. 1 from firm A (firm A fails to protect it even w/ successful own-innov.)

$\Rightarrow$ Why? firm A does not have tech. advantage accumulated

★ Implication: firms w/o tech. advantage would not enhance own-innovation (cannot protect their market)

Proposition 1 (Market-Protection Effect)

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

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

Furthermore,

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

- 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

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

- 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

Extension with Stochastic Learning

Now suppose that firms can fully catch up with the frontier technology with probability ω.

$$\left\{q^{\mathrm{ex}}_{j,t+1}\right\} = \begin{cases} \left\{\eta q_{j,t-1}\right\} & \text{with probability } (1-\omega)x_t \\ \left\{\eta q_{j,t}\right\} & \text{with probability } \omega x_t \\ \varnothing & \text{with probability } 1-x_t, \end{cases} \qquad x_t = \left(\frac{R^{\mathrm{ex}}_t}{\widetilde{\chi}\bar{q}_t}\right)^{\frac{1}{\psi}}.$$

◂ Main

Extension with Stochastic Learning

Own-Innovation with Stochastic Learning

$$\frac{\partial z^1}{\partial \omega}\Big|_{A_1,A_2} = 0, \frac{\partial z^2}{\partial \omega}\Big|_{A_1,A_2} < 0, \frac{\partial z^3}{\partial \omega}\Big|_{A_1,A_2} < 0, and \frac{\partial z^4}{\partial \omega}\Big|_{A_1,A_2} < 0. \frac{\partial x}{\partial \omega}\Big|_{\{A_\ell\}_{\ell=1}^4} > 0.$$

Furthermore, if $\omega = 1$, then firms immediately catch up with the frontier technology and technology gaps degenerate.

$$z^\ell = z \; \forall \; \ell \in \{1,2,3,4\} \quad \text{if } \omega = 1$$

- Given local technology gap, as ω increases, own-innovation decreases (by firms with a positive tech gap), while creative destruction increases
- If learning disappears with $\omega = 1$, incumbents cannot defend competition through own-innovation (This goes back to the world in Ackgit and Kerr 2018)

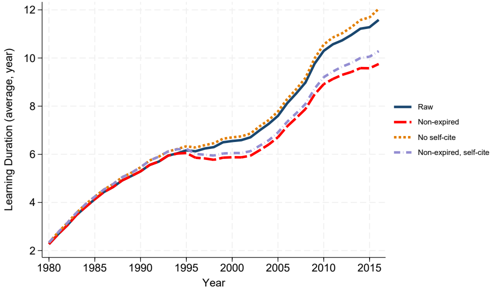
Main

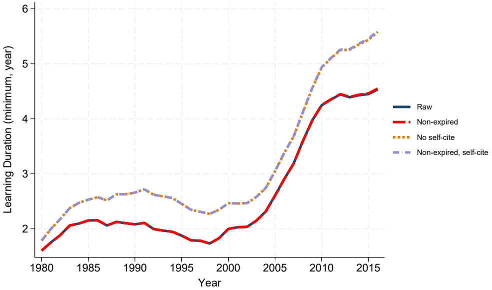
Summary Statistics of Learning Duration (1982-1999)

	Learning Time (year)	
	Average	Minimum
Mean	5.5516	2.4680
Std.	3.1477	2.9066
25%	3.2292	0.5
50%	5.1667	1.4167
75%	7.4292	3.2500
Observations	761,945	761,945

Main

Learning Trends

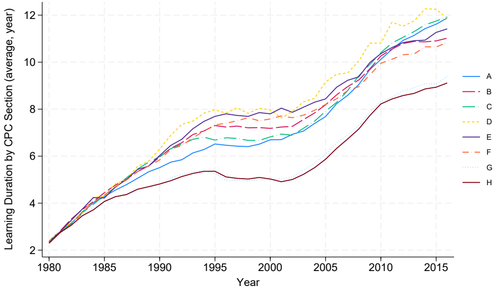


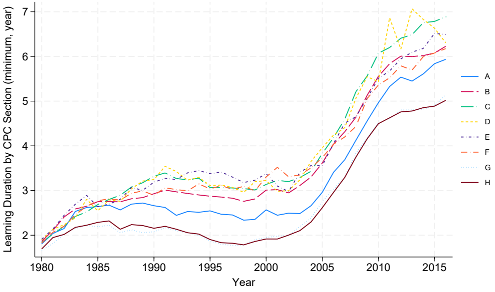


Learning Duration Over Time

Main

Learning Trends

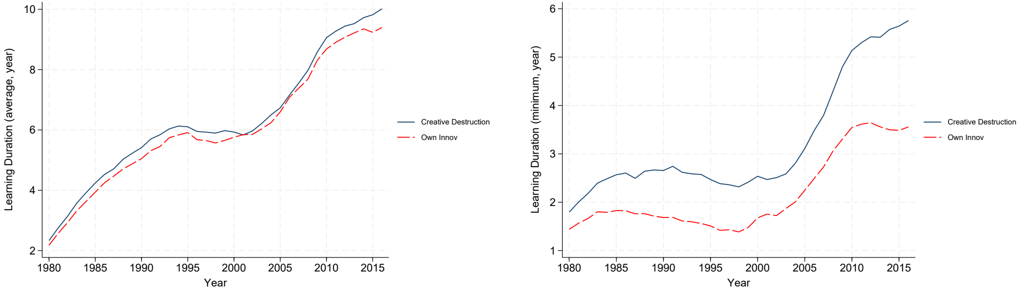




Learning Duration Over Time (by CPC Sections)

Main

Learning Heterogeneity in Innovation



Average and Minimum Learning Duration (Own vs Creative Destruction)

Main

Robustness Test of Learning Predictions

	Citation gaps (average)	Citation gaps (average)	Citation gaps (average)	Citation gaps (minimum)	Citation gaps (minimum)	Citation gaps (minimum)
Self-citation ratio	-1.766***	-1.933***	-1.466***	-2.086***	-1.104***	-1.040***
	(0.020)	(0.021)	(0.015)	(0.017)	(0.018)	(0.014)
Cited patent number	0.015***			-0.041***		
	(0.000)			(0.001)		
CPC class number		0.097***			-0.250***	
		(0.002)			(0.002)	
Std of citation gaps			0.577***			-0.211***
			(0.002)			(0.002)
Observations	740,908	551,654	698,764	740,908	551,654	698,764
Fixed effects	i, ct	i, ct	i, ct	i, ct	i, 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 HS8-level (1)	ΔCN imp NAICS6-level (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

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 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

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)
$\times$ Innovation intensity		-0.195		-0.058
		(0.162)		(0.395)
NTR gap $\times$ $\mathcal{I}_{\{1992\}}$	0.523	0.500	0.252	0.259
	(0.355)	(0.362)	(0.294)	(0.290)
$\times$ 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