The Impact of Regulation on Innovation

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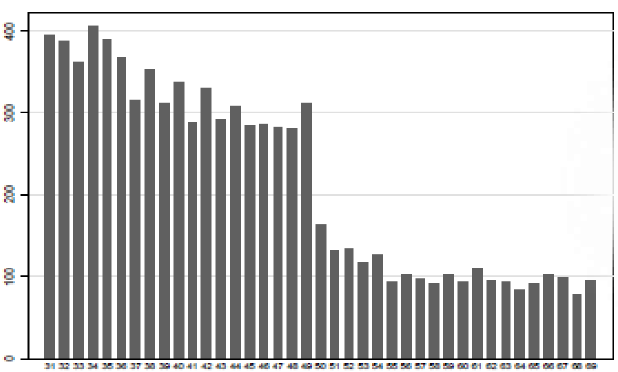
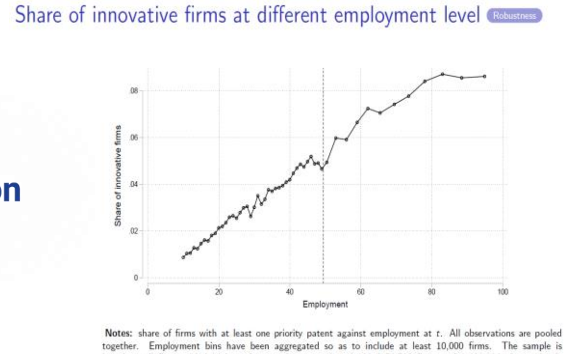
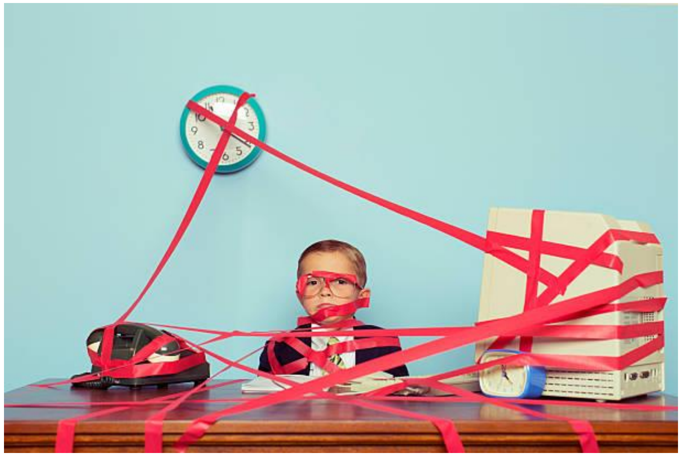


Programme on
Innovation and Diffusion



Introduction

- Long-standing question: how does regulation affect economic performance?
  - In particular, does labor regulation inhibit innovation?



Introduction

- Long-standing question: how does regulation affect economic performance?
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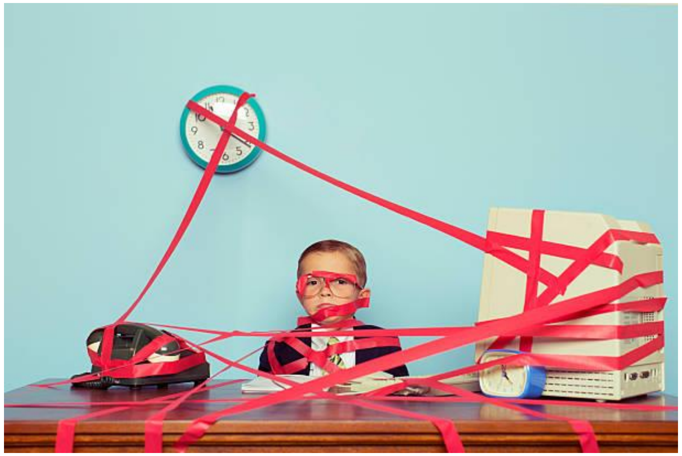
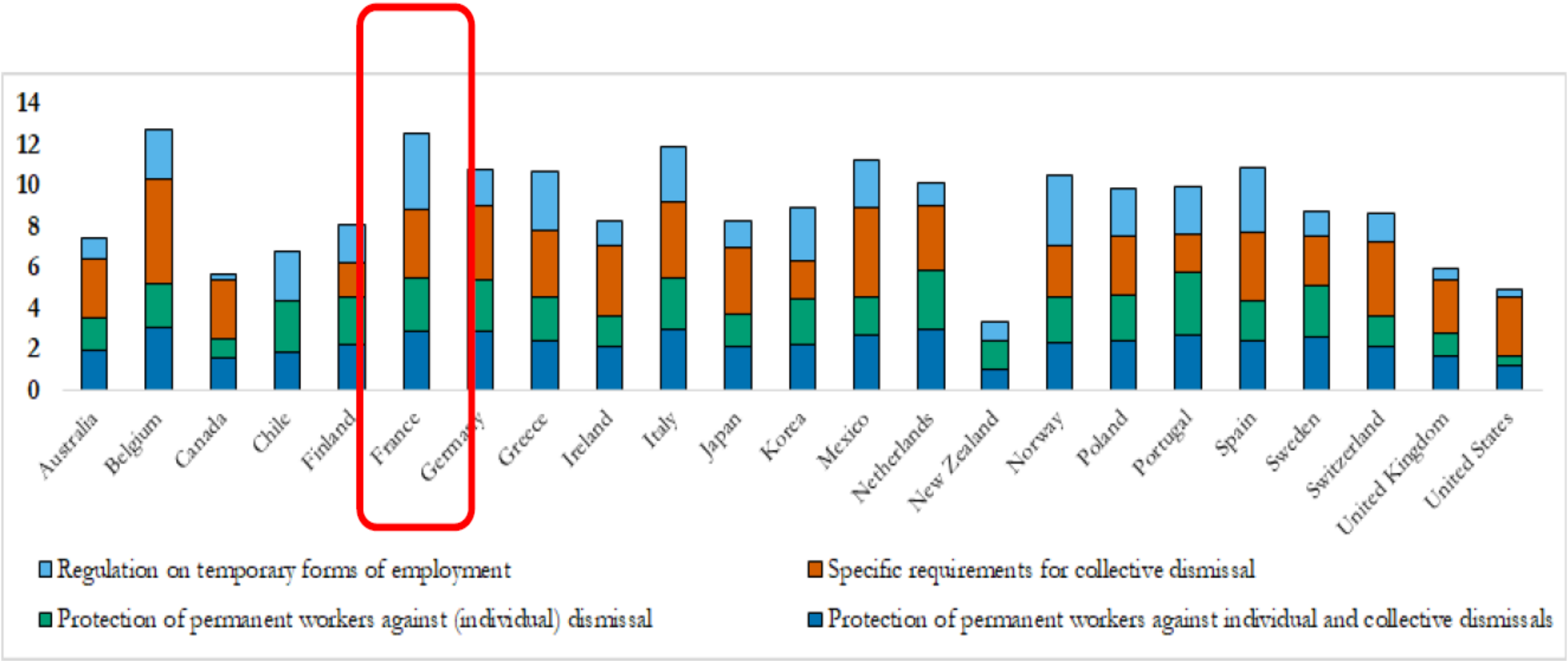
- We develop a heterogeneous firm macro framework with endogenous innovation to study how regulation affects the joint distribution of firm innovation & size.
  - Implement on micro panel data on French firms



France has tough Employment Protection Laws, but do these really cause economic problems?



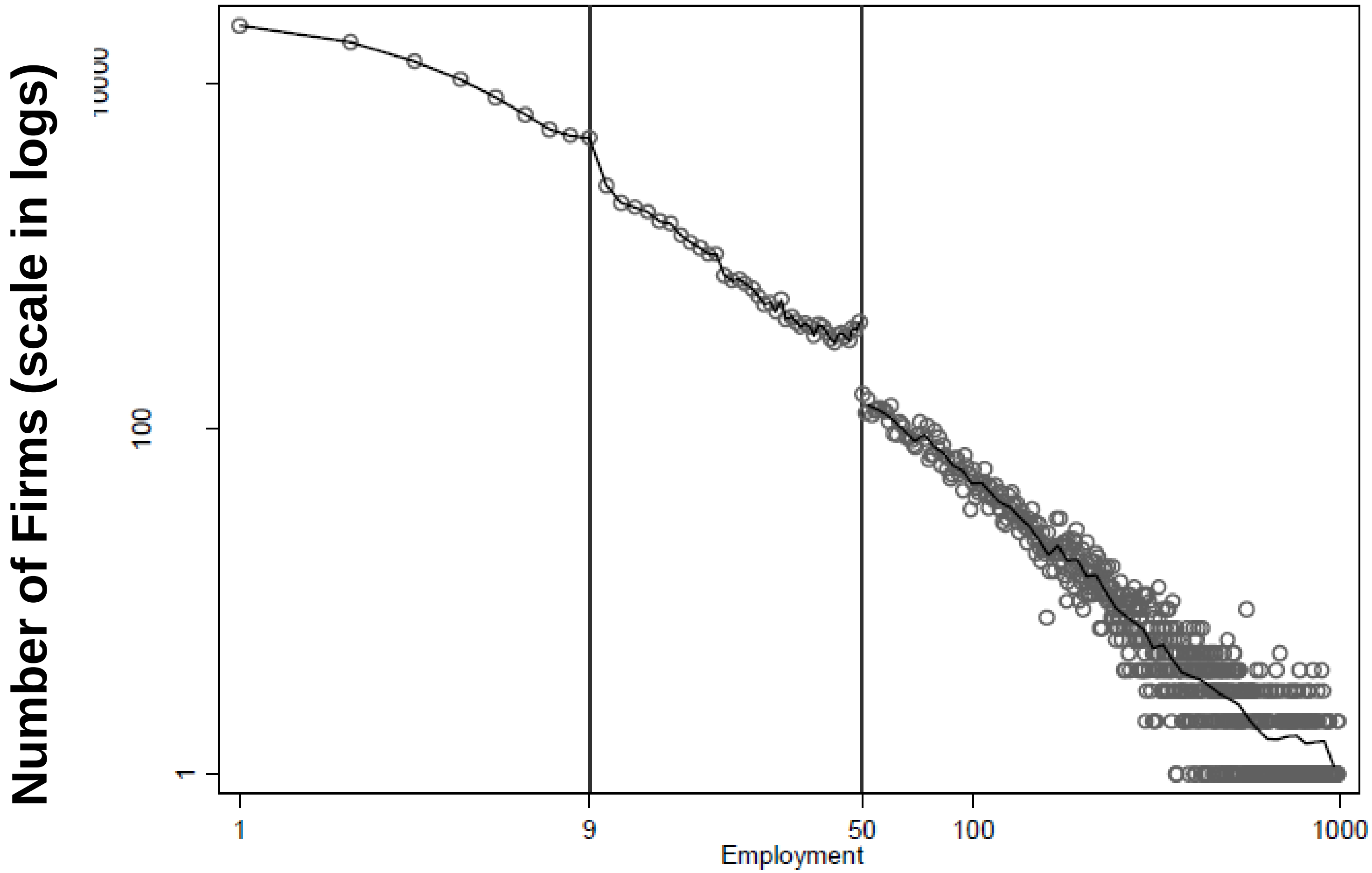
Source: OECD (2019)

Reform Ain't Easy

Empirical Contribution

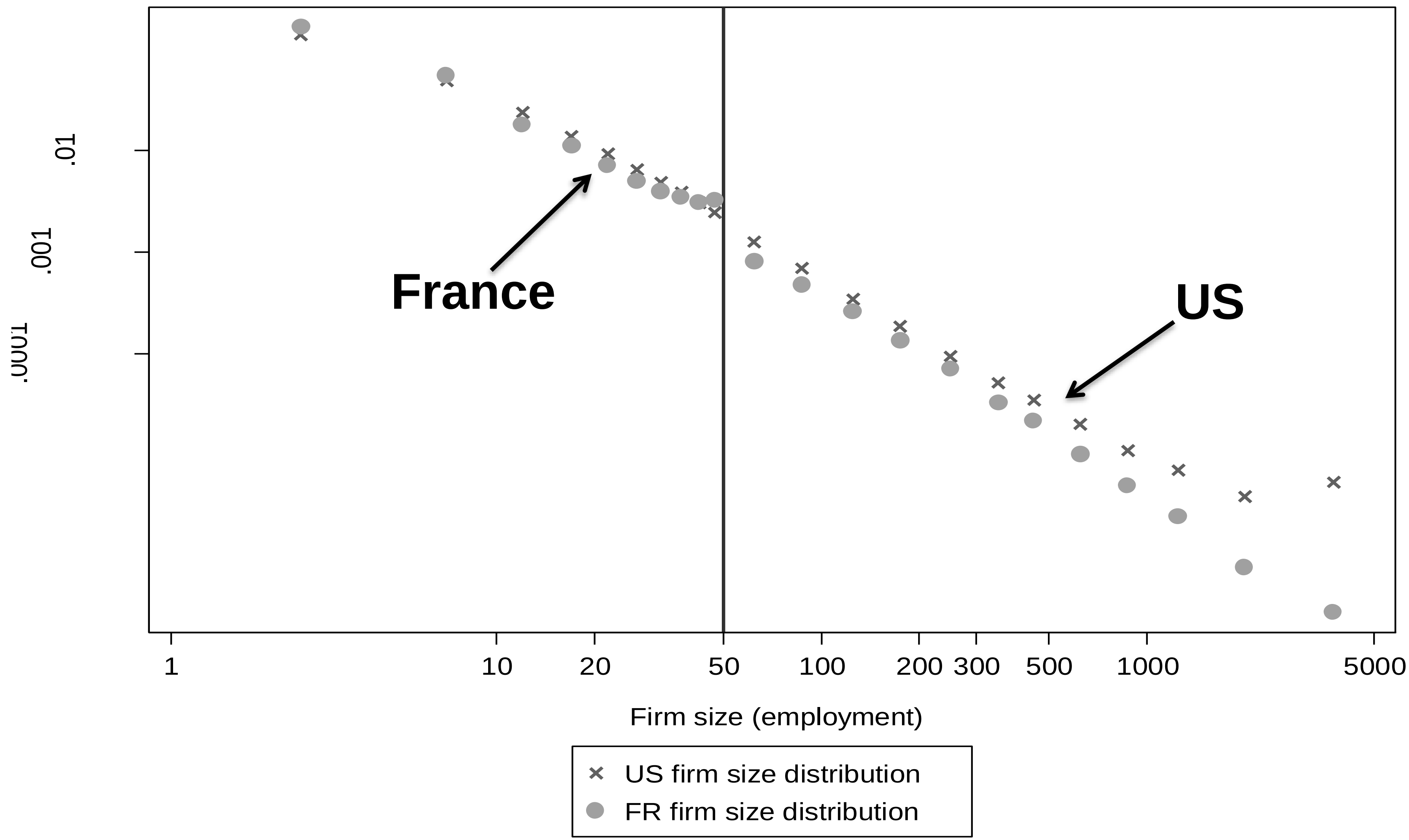
- Many regulations are dependent on firm size & this creates discontinuities that are helpful for identification
- In France, many important labor regulations begin at 50 employees
  - Creation of "work council" ("comité d'entreprise")
  - Firm has to offer union representation
  - Health & safety committee
  - Profit sharing scheme
  - Spend minimum % revenues on worker training
  - Collective dismissal requires "social plan" to facilitate re-employment through training, job search, etc. Negotiated/monitored by unions & Labor Ministry

Firm Size Distribution (log-log scale) follows "broken power law" at regulatory thresholds



Note: Population FICUS data. Both axes on log scale. Another (smaller) increase in regulations at 10 employees, so we focus on 10+ sample.

FIRM SIZE DISTRIBUTION: US DOES NOT HAVE A BREAK AT 49 WORKERS LIKE FRANCE



Summary of Paper (1/2)

- Consistent with the qualitative predictions of the theory, in the data we find evidence that regulation **discourages** innovation through an implicit tax when crossing threshold:
  - **Static Non-parametric analysis**
    - See "innovation valley" in innovation-firm size relationship just before the threshold
    - See a fall in the slope of in innovation-firm size relationship after crossing threshold

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    - See “innovation valley” in innovation-firm size relationship just before the threshold
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  - **Dynamic parametric analysis:**
    - Exploit exogenous export market size shocks. These stimulate innovation (e.g. Acemoglu & Linn, 2004), but much less so for firms just below regulatory threshold

Summary of Paper (2/2)

- Structurally quantifying model parameters, we find that:
  - Aggregate Innovation is **~5.8%** lower due to regulation
  - Decompose aggregate effect into components
    - Vast majority of this effect due to less innovation per firm, but some contribution from shifting size distribution to left (misallocation) & lower entry
    - Calculate lower bound to welfare loss (**~2.3%),** approximately doubling the static losses

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    - Calculate lower bound to welfare loss (**~2.3%),** approximately doubling the static losses
- **Extension:** Our effect mainly via reducing **incremental** innovations. Extend theory to allow for different types of R&D. For firms just below threshold, if they innovate, they "Swing for the fence" with radical innovation

SOME RELATED LITERATURE

- **Labor Regulation & Innovation:** Acharya et al (2013a,b); Griffith and Macartney (2014); Garcia-Vega et al (2019); ***Mukoyama & Osotimehin (2019)***
- **Labor laws, Technology adoption & Productivity:** Autor et al (2007), *Amirapu & Gechter (2020),* Bartelsman et al (2016); Boeri et al (2017); Braguinsky et al (2011); Ceci-Renaud & Chevalier (2011); ***Garicano et al (2016);*** Gourio & Roys (2014); Haltiwanger et al (2014); Kahn (2007); Samariego (2006);
- **Market size & innovation:** Acemoglu & Linn (2004); Schmookler (1966); Shleifer (1986); Barlevy (2007); Aghion et al (2018), Acemoglu et al (2018)
- **Size-related Distortions & Productivity**: Restuccia & Rogerson (2008); Hopenhayn (2014); Hsieh & Klenow (2009)
- **Tax:** Chetty et al (2011), Kleven & Waseem (2013); Akcigit et al (2022); Akcigit & Stantcheva (2022)

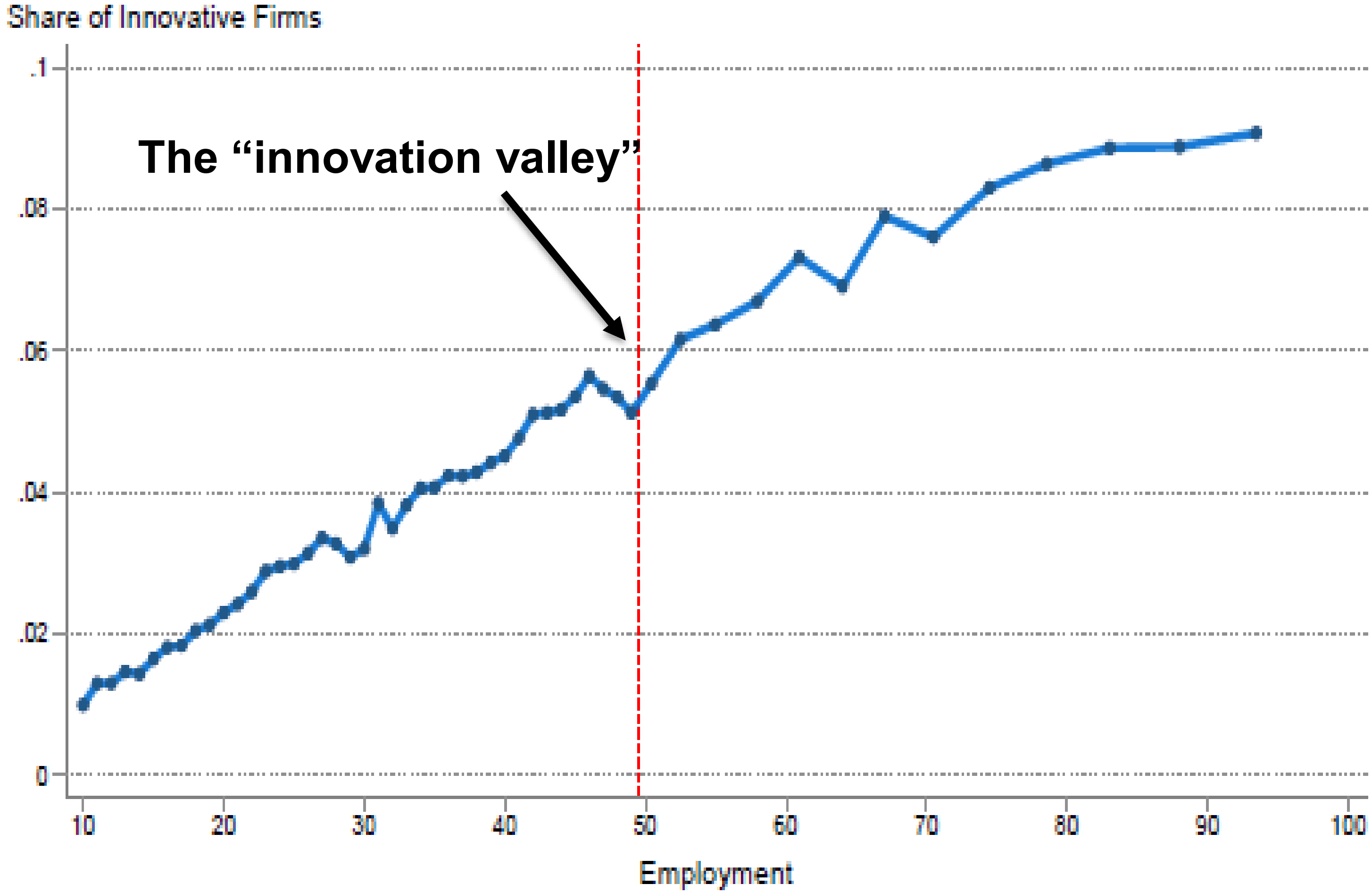
OUTLINE

1. **Data and Basic Facts**
2. Model
3. Empirical Strategy
4. Results
5. Aggregate Implications
6. Extensions

Data

- **FICUS:** Universe of French firms between 1994 - 2007
  - Mandatory fiscal returns of all firms
- **PATSTAT**: 80 patent offices (USPTO, EPO, JPO, etc.). Match to French firms using supervised Machine Learning algorithm (Lequien et al, 2018). Priority applications
- **Customs** data on all exports (with origin-destination product-country) 1994-2012 matched to firm level. UN **COMTRADE**

Share of innovative firms by firm size: Innovation valley before 50 threshold & flattening slope after



Notes: Share of firms with at least one priority patent in 2007; 182,347 firms

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Basic Framework

- Schumpeterian growth + Klette-Kortum (2004) firm dynamics. Add in regulatory **marginal tax**, τ, for firms > 49 workers.
- Continuum of product lines/varieties, n, indexed by j, each produced monopolistically by most recent innovator on line j using labor
- Firm's innovation (Z_i, Poisson arrival rate) depends on its R&D spend, R_i (& knowledge stock reflected in in size, n_i)

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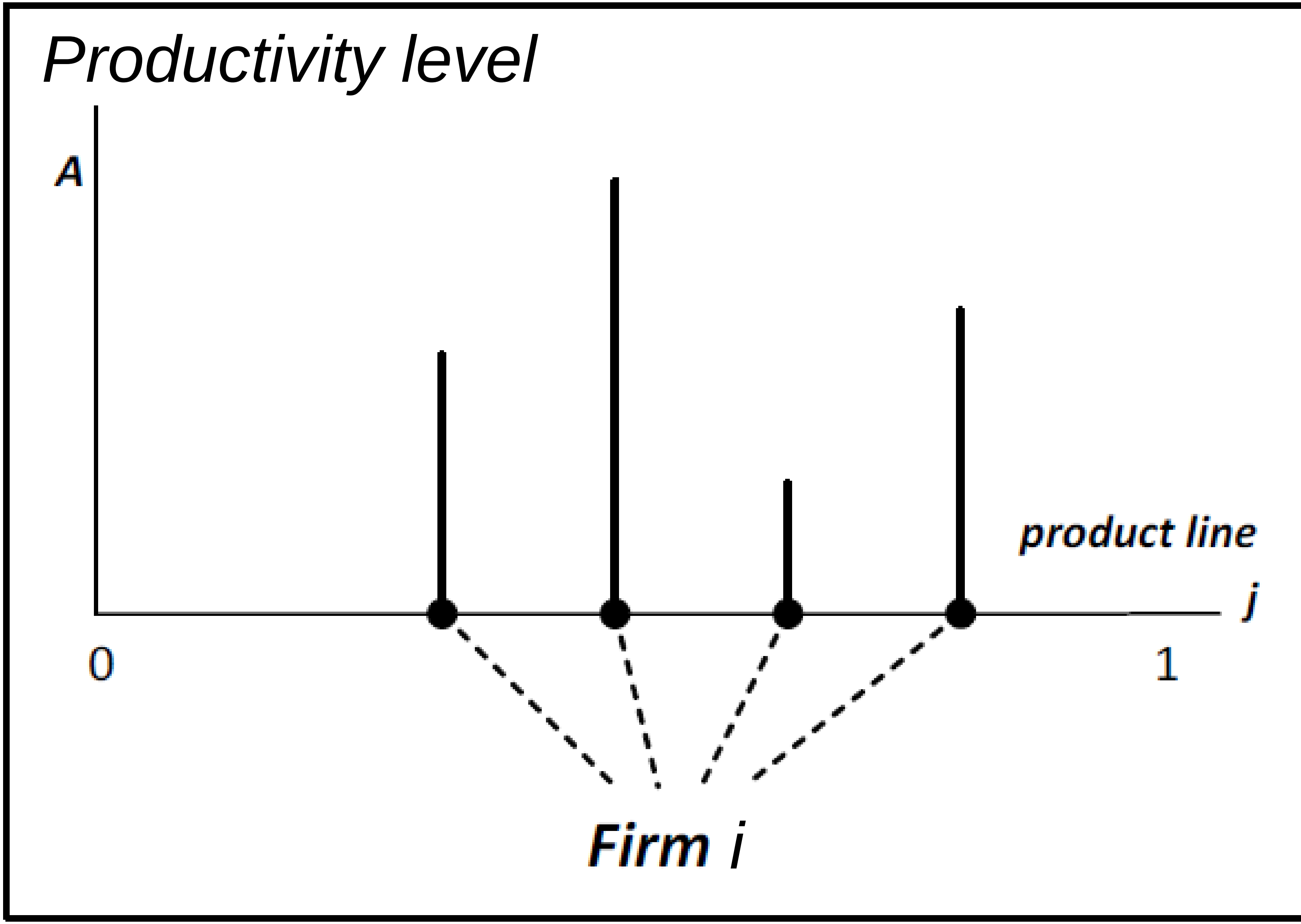
- Firm's innovation (Z_i, Poisson arrival rate) depends on its R&D choice (& knowledge stock reflected in in size, n_i)
- Every product line subject to risk of creative destruction at prob. *x* by rival incumbents innovating or by new entrant (z_e)
- An innovating firm improves productivity by $\gamma > 1$ over existing technology on one random product (now produces $n + 1$ lines)

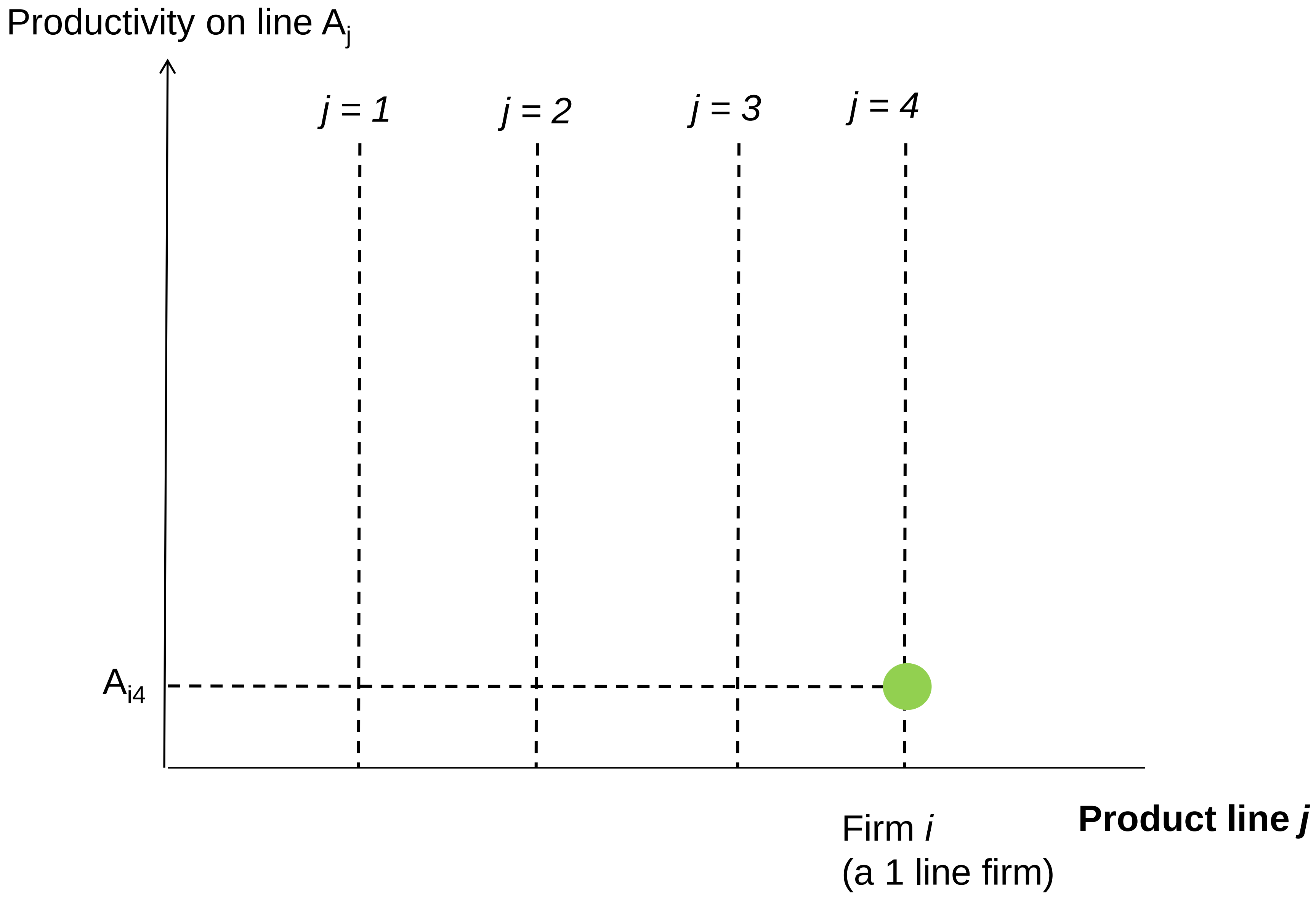

Productivity level
A
product line
j
0
1
Firm i

Lifecycle of a firm

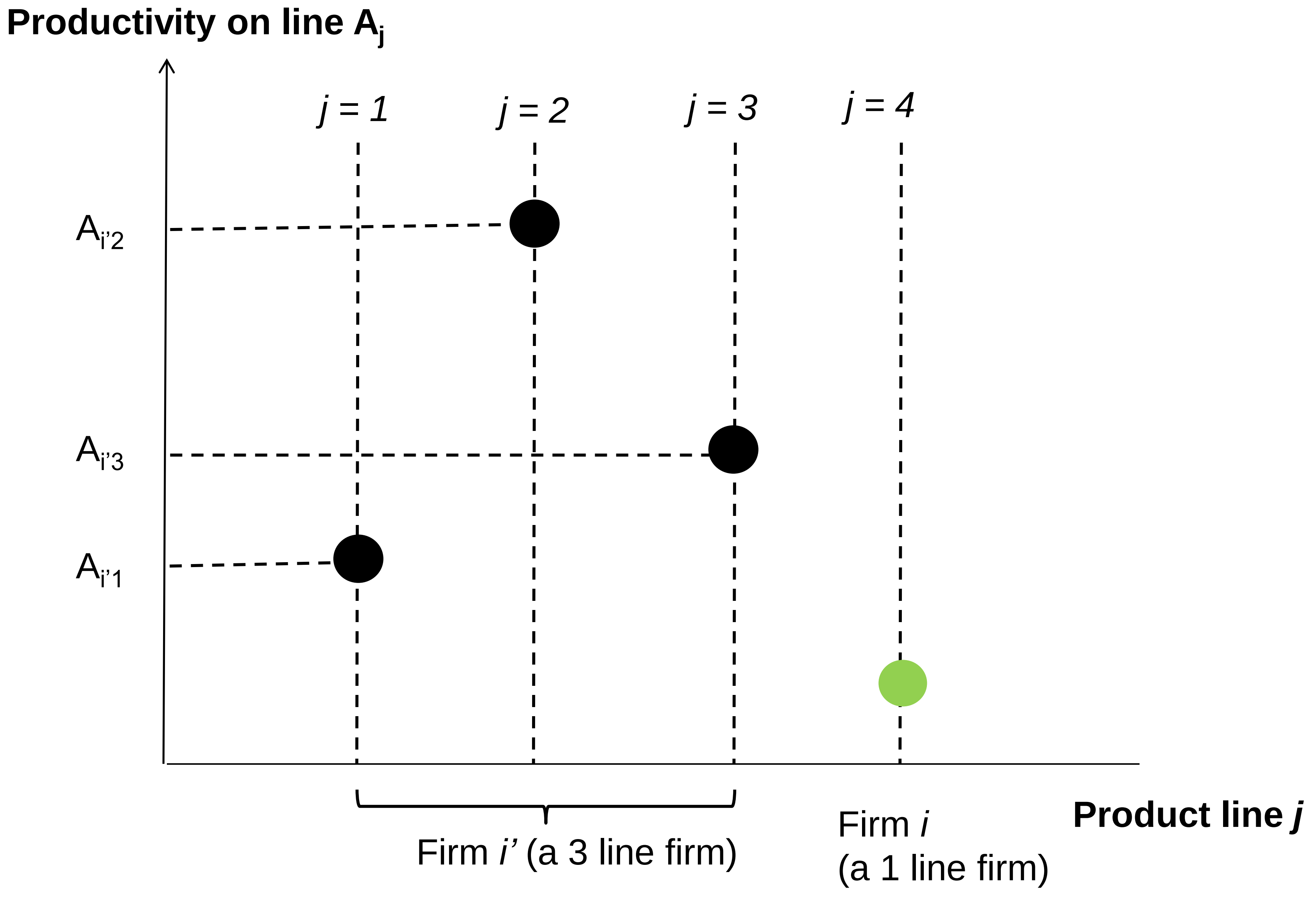
- For expositional purposes, consider owner that lives 2 periods (firms can live forever)
  - Before period 1, the owner inherits a firm of size n
  - In period 1 she chooses her innovation intensity, z
  - In period 2, she chooses inputs & takes profits. Owner dies and successor takes over firm

- In general model (Appendix C.3) we allow owners to live multiple periods and same intuitions go through

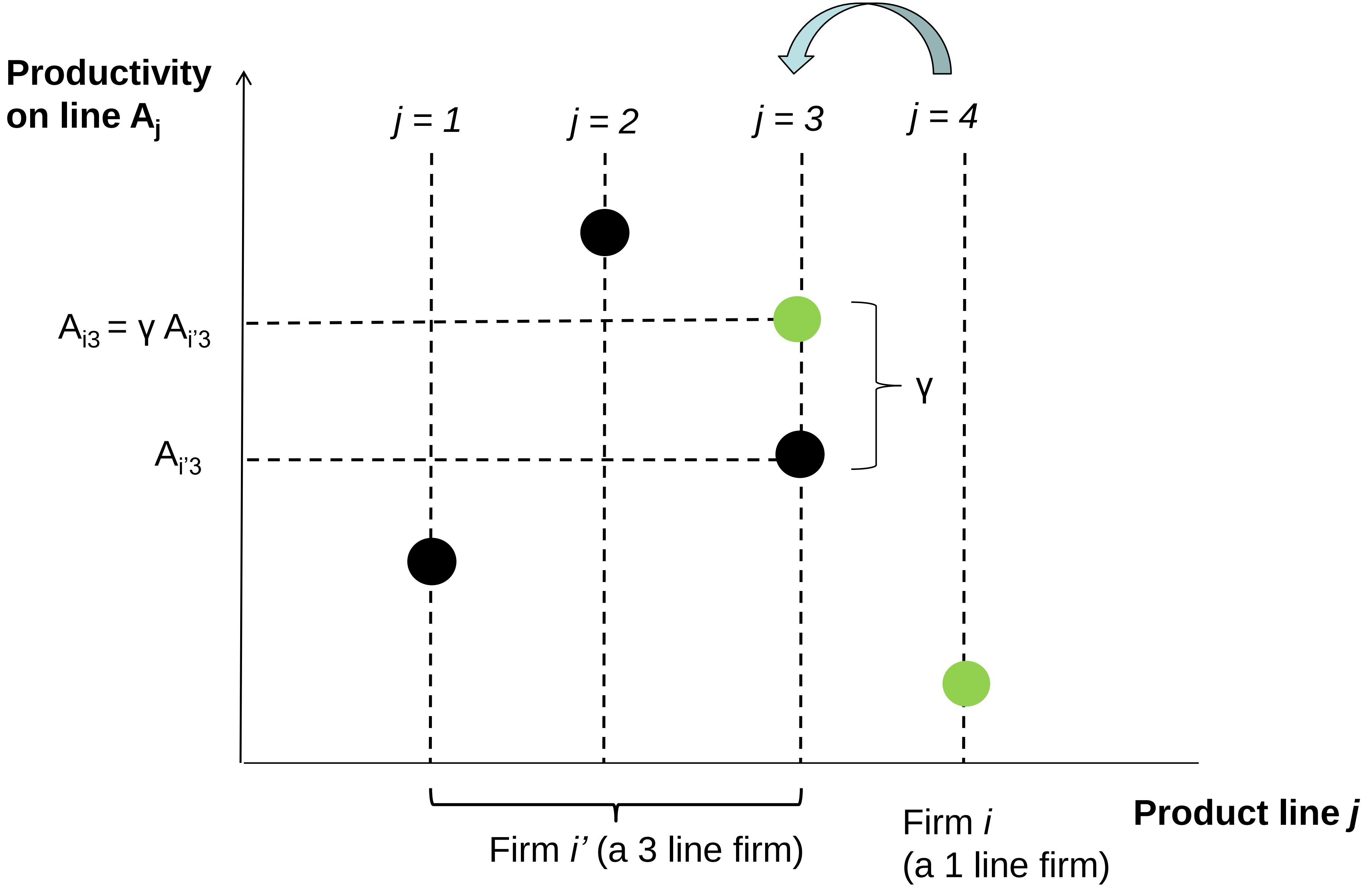
Firm *i* produces single line (*j*=4) with productivity A_{i4}



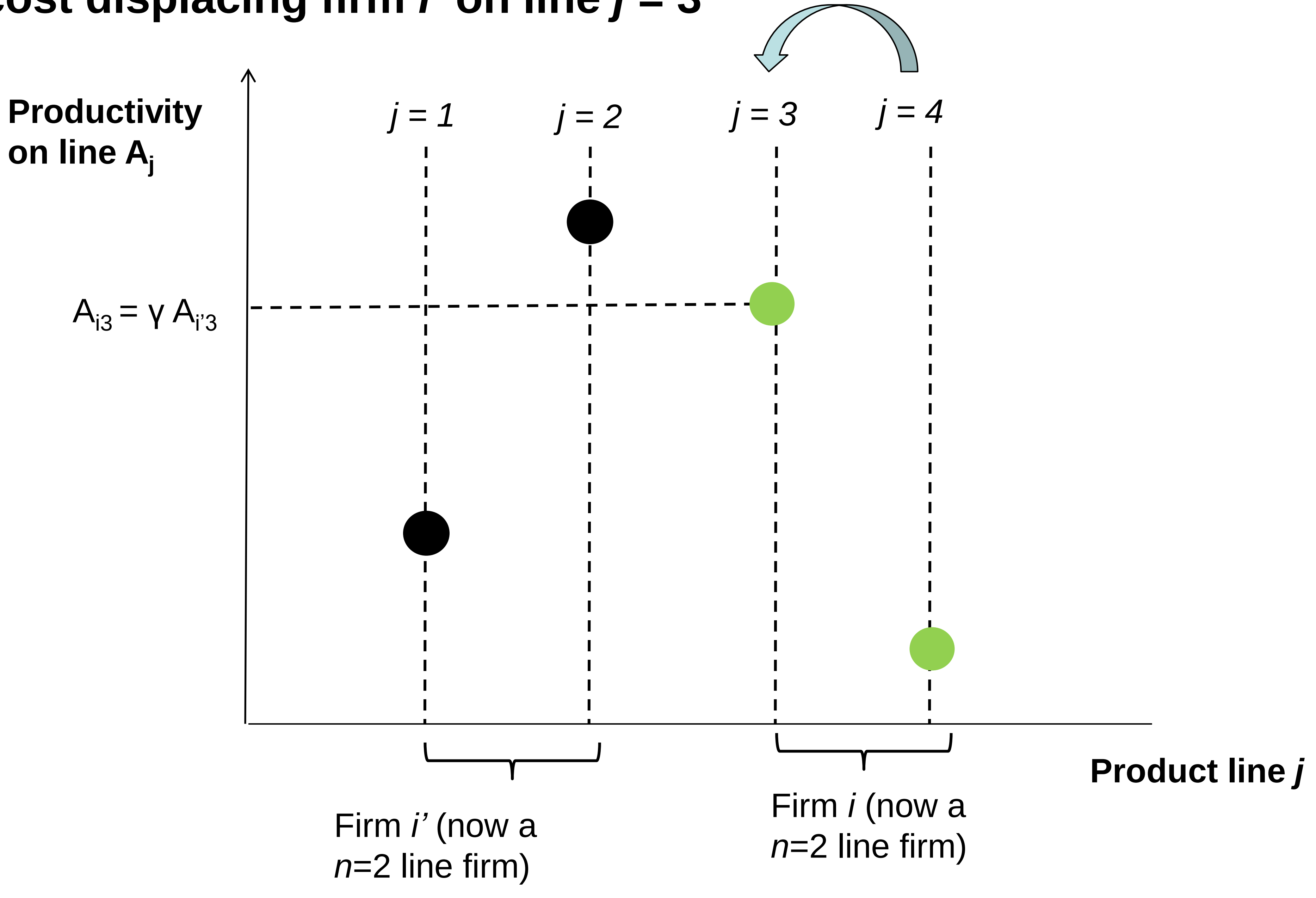
Firm *i'* has 3 lines (*j* = 1,2,3) with productivities ($A_{i'1}, A_{i'2}, A_{i'3}$)



Firm *i* innovates and enters line *3* with productivity $A_{i3} = \gamma A_{i'3}$



Creative destruction: Firm *i* limit prices at firm *i*'s marginal cost displacing firm *i'* on line *j* = 3



Firm's problem

- If firm employment exceeds threshold $\bar{l}$ *(=49;* or equivalently produces more than $\bar{n}$ lines), it incurs a tax on profits, τ

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- The firm chooses *z* (R&D per line) to maximize NPV:

Flow profit per line today + next period (if no innovation)

Discounted Incremental profit from innovating (prob = z) & producing n+1 lines

$$\underbrace{(1+\beta)\pi(n)} + \underbrace{\beta z[(n+1)\pi(n+1) - n\pi(n)]}$$
$$+\underbrace{\beta x[(n-1)\,\pi(n-1) - n\pi(n)]} - \underbrace{\zeta z^{\eta}}$$

Discounted Incremental loss from being replaced (prob = x) by another firm & producing n -1 lines

R&D cost

where $\pi(n) = 1 - \frac{1}{\gamma}$ if $n < \bar{n}$ and $\pi(n) = \left(1 - \frac{1}{\gamma}\right)(1-\tau)$ if $n \geq \bar{n}$

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Firm's optimal innovation <u>per line</u>, *z(n)* = *(Z/n)*: Three Regimes

Small firms
Well below threshold $\left(\frac{\beta(\gamma-1)}{\gamma\zeta\eta}\right)^{\frac{1}{\eta-1}}$ $if\ n < \bar{n} - 1$

Medium firms
Just below threshold $if\ n = \bar{n} - 1$

Big firms
above threshold $if\ n \geq \bar{n}$

$\bar{n}$ is the regulatory threshold

Firm's optimal innovation <u>per line</u>, *z(n)* = *(Z/n)*: Three Regimes

Discount factor *Innovation step size*

<u>Small firms</u>
Well below threshold

$$\left(\frac{\beta(\gamma-1)}{\gamma\zeta\eta}\right)^{\frac{1}{\eta-1}} \quad if\ n < \bar{n}-1$$

Parameters in the R&D cost function:
ζ is a scale & η a concavity parameter

Firm's optimal innovation per line, *z(n)* = *(Z/n)*: Three Regimes

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$$\left(\frac{\beta(\gamma-1)}{\gamma\zeta\eta}\right)^{\frac{1}{\eta-1}} \quad if\ n < \bar{n}-1$$

Medium firms
Just below threshold

$$\left(\frac{\beta(\gamma-1)(1-\tau\bar{n})}{\gamma\zeta\eta}\right)^{\frac{1}{\eta-1}} \quad if\ n = \bar{n}-1$$

Big firms
above threshold

$$\left(\frac{\beta(\gamma-1))(1-\tau)}{\gamma\zeta\eta}\right)^{\frac{1}{\eta-1}} \quad if\ n \geq \bar{n}$$

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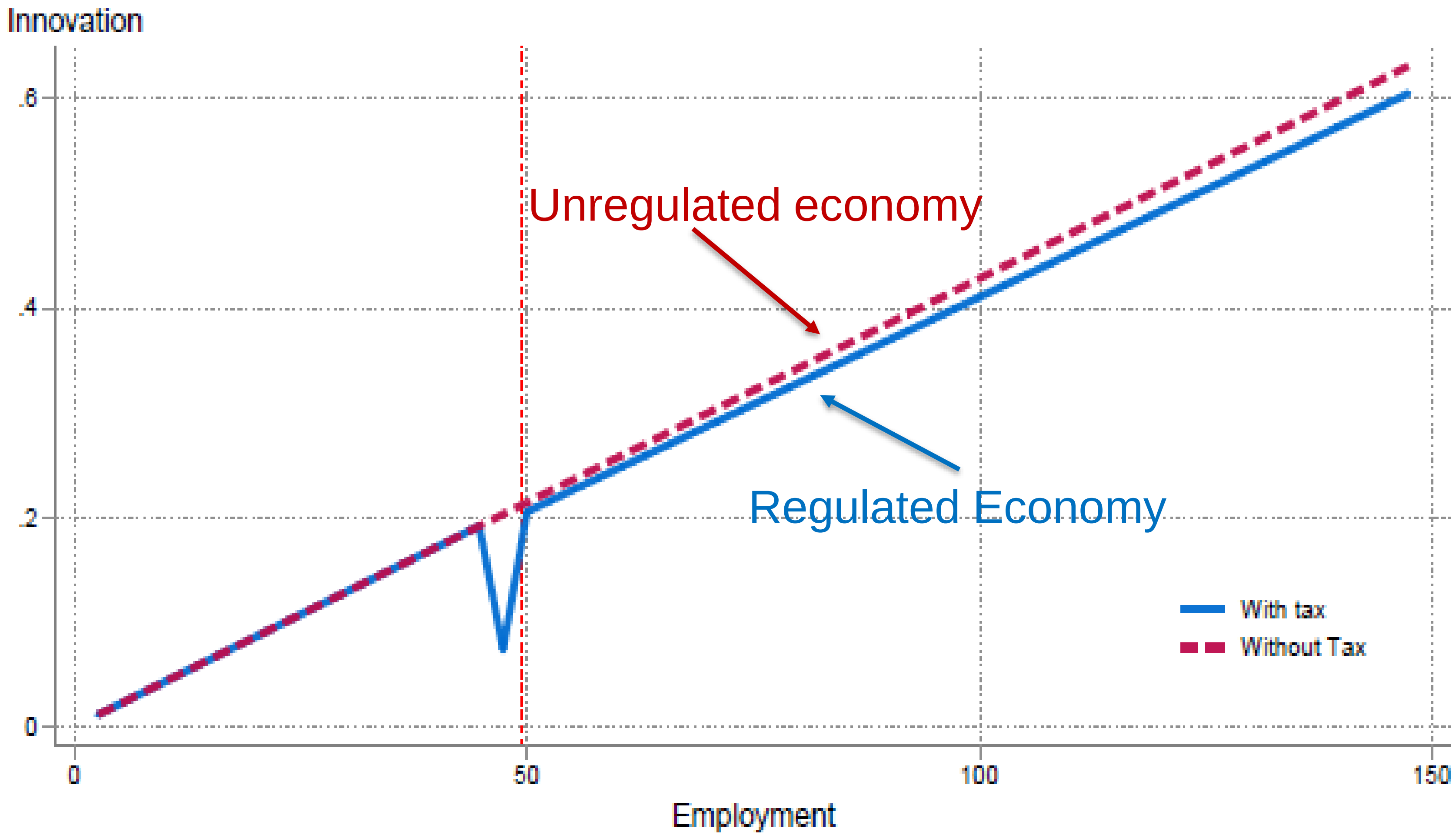
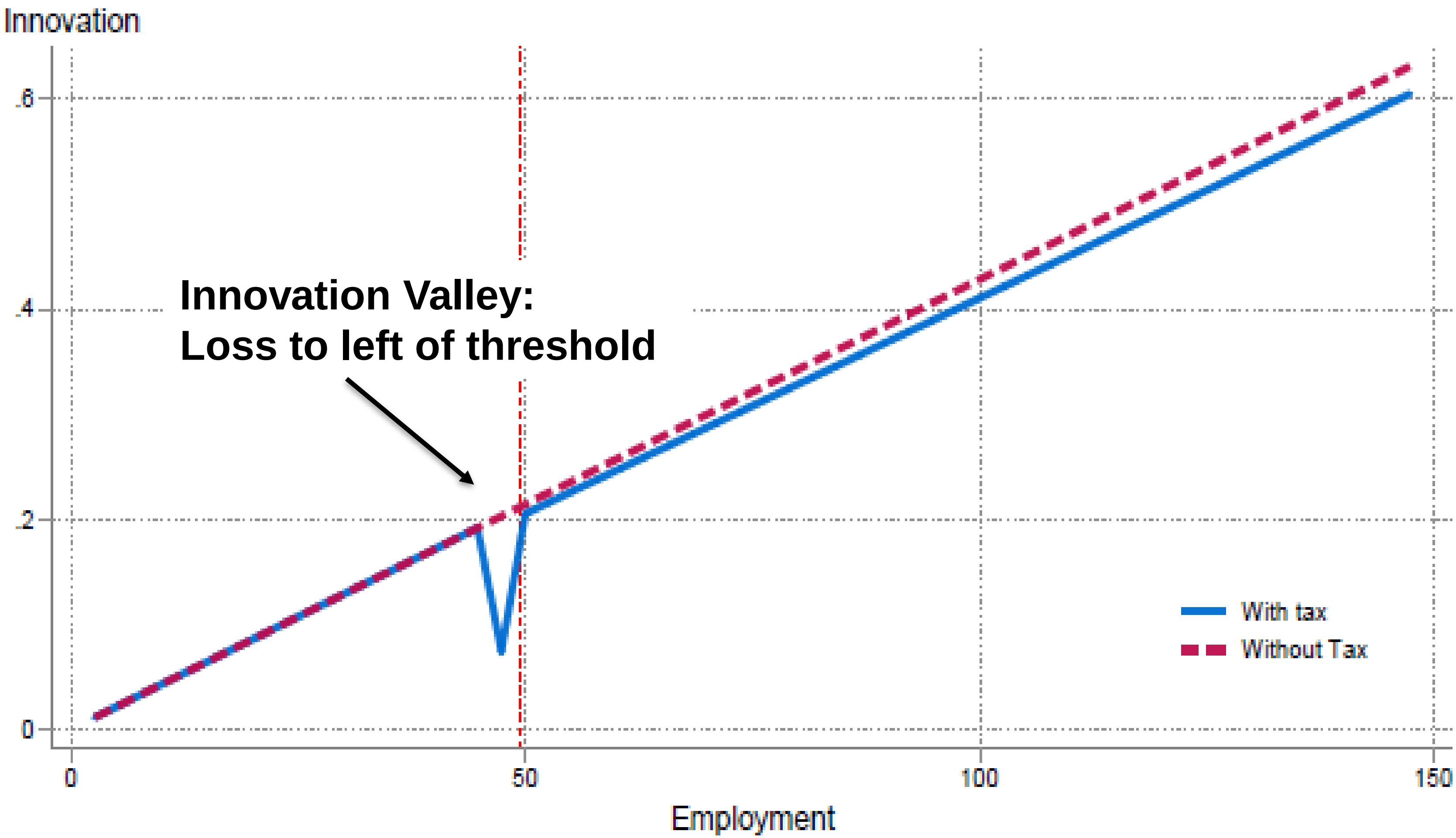
Fig. 3(a): Firm Innovation (*Z*) and Firm employment



Notes: This is the total amount of innovation ($Z(n)$) by firms of different sizes (employment, $L = n/(\gamma\omega)$) by aggregating innovation intensities $z(n)$ across all its product lines (n) according to our baseline theoretical model. The y-axis is the Poisson innovation flow rate (the probability of innovating and adding a line. We use our baseline calibration values of tau=0.025, gamma=1.3, eta=1.5, beta/zeta=0.23 and omega=0.26 for illustrative purposes (see section 4 for a discussion).

Fig 3(a): Two types of firm-level Innovation losses



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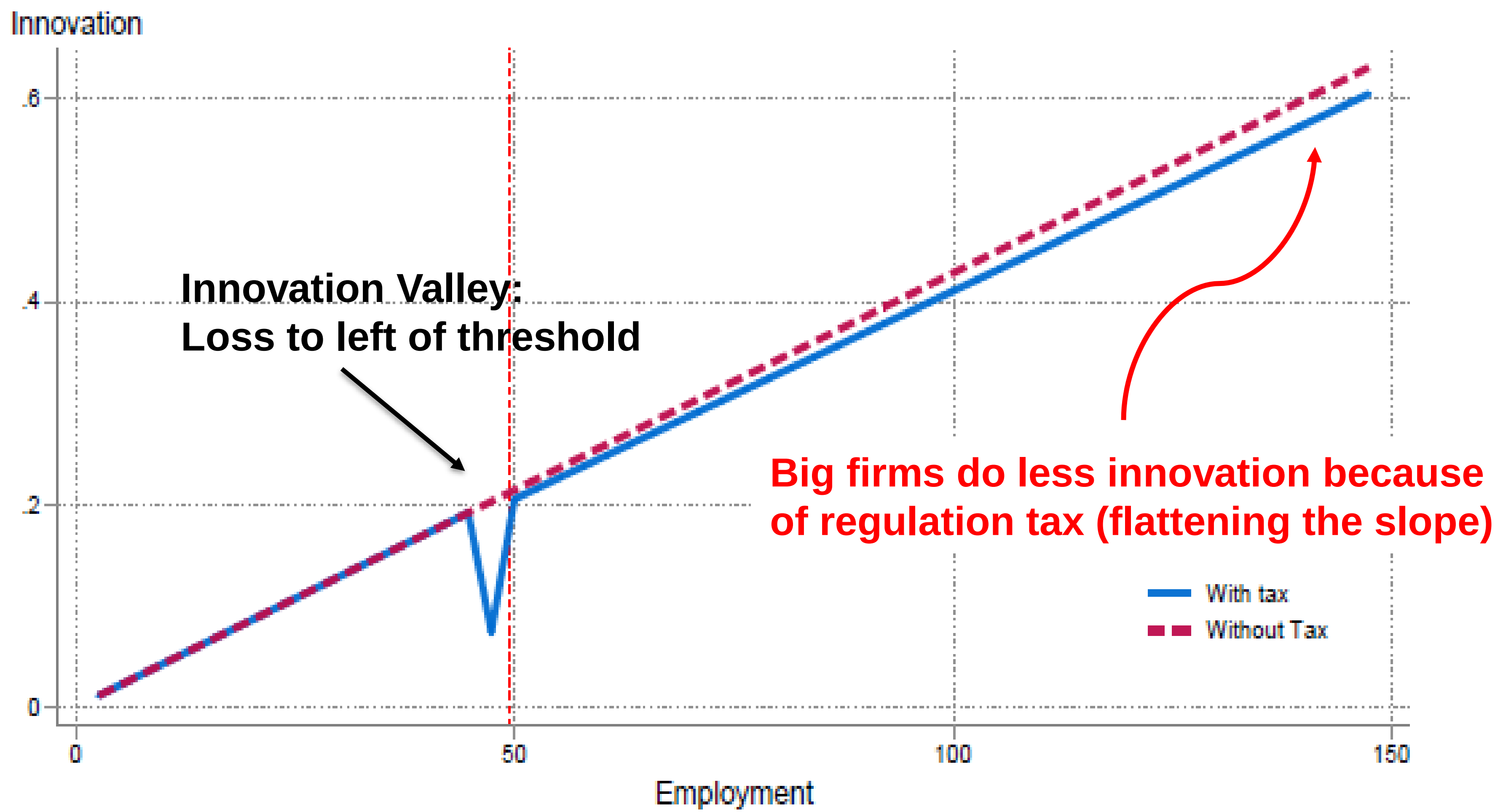

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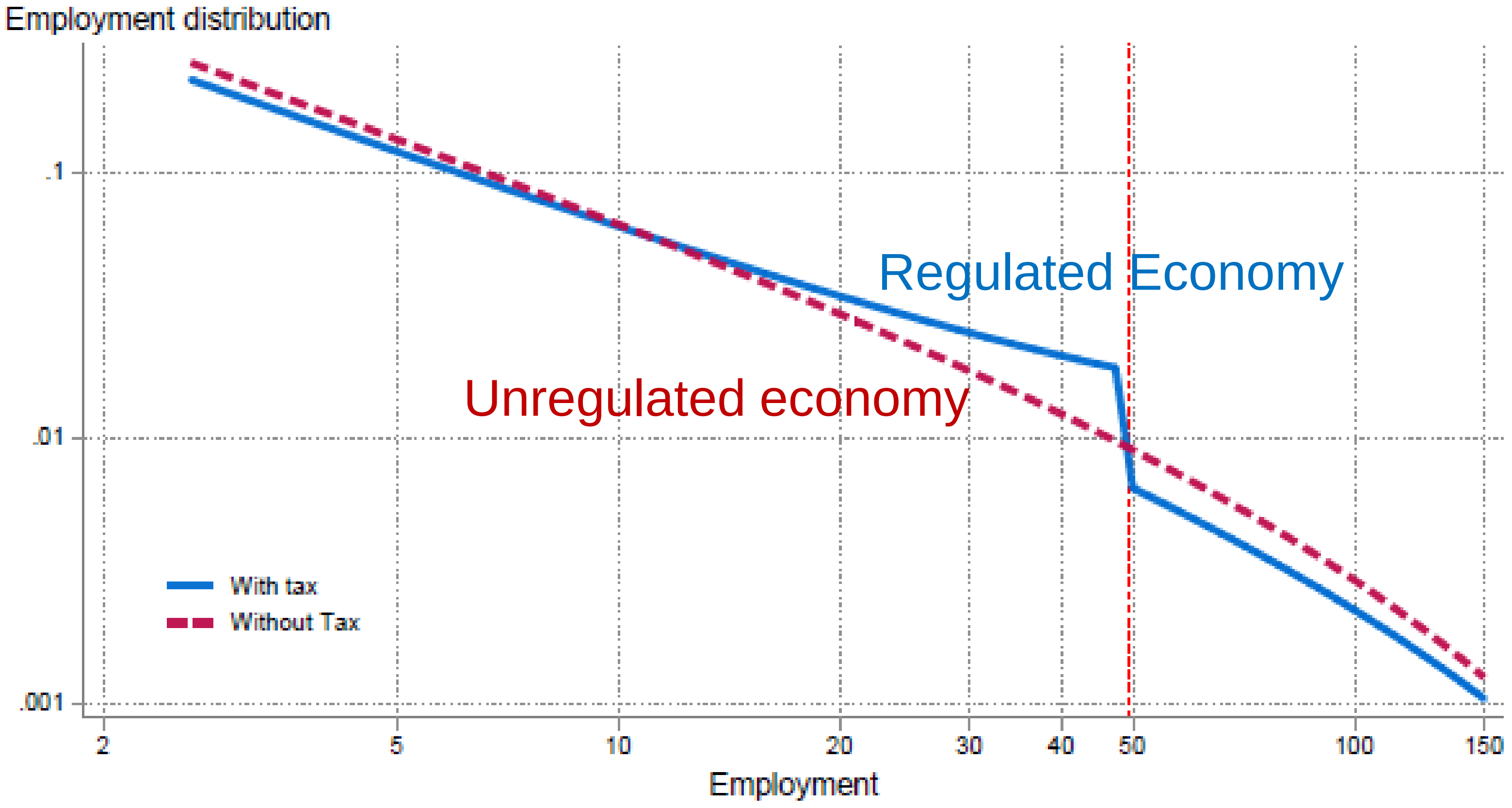
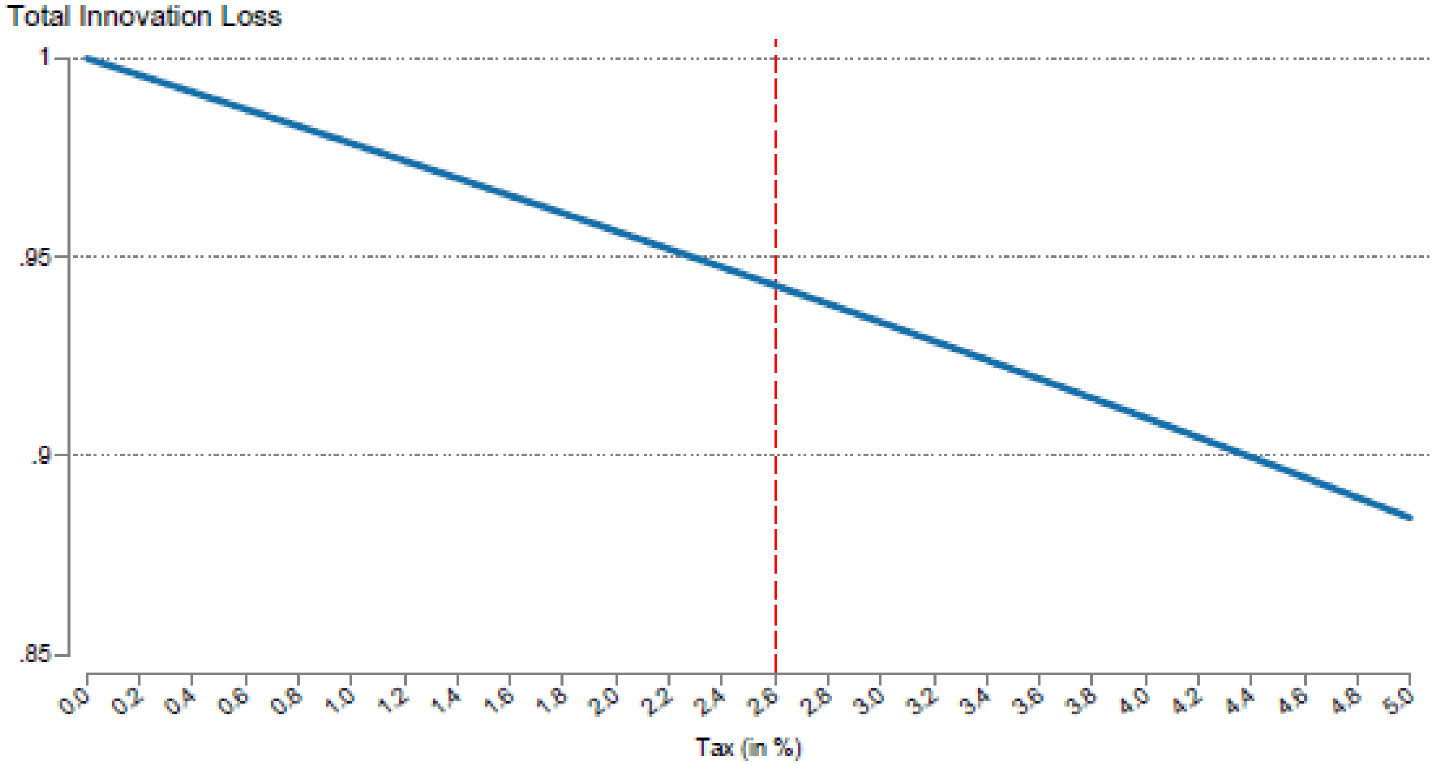
Fig 3(b): Steady State Firm Size distribution with and without regulation



Note: μ(n) is # firms of exactly size n. In steady state inflows equal outflows & we can describe law of motion of μ(n).

Fig 4: Putting it all together - aggregate Loss of Innovation as a function of regulation

Figure 4: Aggregate economy-wide innovation as a function of the intensity of regulation



Notes: We simulate the amount of aggregate innovation in different economies relative to an unregulated benchmark economy as the intensity of regulation changes as indicated by the magnitude of the implicit tax (τ). For example, if $\tau = 2\%$, aggregate innovation is about 0.96 relative to the benchmark, i.e. 4% lower. Parameter values are the same in regulated and regulated economies (as in notes to Figure 1) except we vary the value of τ.

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Measuring exogenous shock to market size

- Construct demand shock based on growth of firm's overseas market size (Hummels et al, 2014):
- French customs data gives us exports of all **firm** *i*'s (HS6) **products** *s* to destination **country** *j* at **time** *t*
- Firm's export share in base year t_0 is $\omega_{i,s,j,t0}$
- We interact this weight ($\omega_{i,s,j,t0}$) with growth in imports ($\tilde{\Delta} I_{s,j,t}$) of this country-product (excluding France), to construct the IV

$$\Delta S_{it} = \sigma_{i,t_0} \sum_{s,j \in \Omega(i,,t_0)} \omega_{i,s,j,t_0} \tilde{\Delta} I_{s,j,t}$$

- Where σ_{i,t_0} is initial exports/sales

Patent Growth Equation

$$\tilde{\Delta}Y_{i,t} = \boxed{b_3\left[\Delta S_{i,t-2} * l^*_{i,t-2}\right]} + b_0 \Delta S_{i,t-2} + b_1 l^*_{i,t-2}$$
$$+ b_2\left[\Delta S_{i,t-2} * P\left(\log\left(l_{i,t-2}\right)\right)\right] + \phi P\left(\log\left(l_{i,t-2}\right)\right) + \psi_s + \tau_t + \epsilon_{it}$$

- l^*_i = 1 if firm has between 45 and 49 employees & zero otherwise; l_i = firm employment;
- $P\left(\log(l_{i,t-2}\right)$ polynomial to flexibly control for size
- ψ_s = industry dummies; τ_t = year dummies
- **<u>Key Hypothesis:</u>** $b_3 < 0$**:** firms increase innovation by less to a positive shock when just below the threshold
- Patent growth in "DHS" form:

$$\tilde{\Delta}Y_{i,t} = \begin{cases} \frac{Y_t - Y_{t-1}}{Y_t + Y_{t-1}} & \text{if } Y_t + Y_{t-1} > 0 \\ 0 & \text{otherwise} \end{cases}$$

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Tab 2: Demand shocks have weaker effects on innovation just below the regulatory threshold

	(1)
$Shock_{t-2} \times L^{*}_{t-2}$	
L^{*}_{t-2}	
$Shock_{t-2}$	1.104**
	(0.488)
$log(L)_{t-2}$	
$Shock_{t-2} \times log(L)_{t-2}$	
$log(L)^{2}_{t-2}$	
$Shock_{t-2} \times log(L)^{2}_{t-2}$	
$\Delta log(L)_{t-2}$	
Fixed Effects	
Sector×Year	✓
Firm	
Number Obs.	142,474

Note: SE clustered by 3-digit industry. All models include 3-digit industry dummies and year effects

Tab 2: Demand shocks have weaker effects on innovation just below the regulatory threshold

	(1)	(2)
$Shock_{t-2} \times L^{*}_{t-2}$		
L^{*}_{t-2}		
$Shock_{t-2}$	1.104**	-4.476**
	(0.488)	(2.034)
$log(L)_{t-2}$		-0.049
		(0.038)
$Shock_{t-2} \times log(L)_{t-2}$		1.723**
		(0.642)
$log(L)^{2}_{t-2}$		
$Shock_{t-2} \times log(L)^{2}_{t-2}$		
$\Delta log(L)_{t-2}$		
Fixed Effects		
Sector×Year	✓	✓
Firm		
Number Obs.	142,474	142,474

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Tab 2: Demand shocks have weaker effects on innovation just below the regulatory threshold

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$Shock_{t-2} \times L^{*}_{t-2}$				-5.018**	-6.135***	-5.555**	-6.560**
				(2.229)	(2.195)	(2.264)	(2.758)
L^{*}_{t-2}				0.043	0.077	0.069	-0.011
				(0.104)	(0.129)	(0.107)	(0.185)
$Shock_{t-2}$	1.104**	-4.476**	7.397	1.418**	-5.293**	6.130	-5.547**
	(0.488)	(2.034)	(6.364)	(0.512)	(2.483)	(6.258)	(2.396)
$log(L)_{t-2}$		-0.049	-0.017		-0.057	-0.026	-0.111
		(0.038)	(0.162)		(0.036)	(0.162)	(0.189)
$Shock_{t-2} \times log(L)_{t-2}$		1.723**	-6.061		2.025**	-5.305	2.123**
		(0.642)	(4.603)		(0.816)	(4.526)	(0.807)
$log(L)^{2}_{t-2}$			-0.005			-0.005	
			(0.029)			(0.029)	
$Shock_{t-2} \times log(L)^{2}_{t-2}$			1.097			1.175	
			(0.759)			(0.749)	
$\Delta log(L)_{t-2}$							
Fixed Effects							
Sector×Year	✓	✓	✓	✓	✓	✓	✓
Firm							✓
Number Obs.	142,474	142,474	142,474	142,474	142,474	142,474	142,474

Note: SE clustered by 3-digit industry. All models include 3-digit industry dummies and year effects

Fig 6: Implied Marginal effect of demand shocks on innovation by firm size

Note: These are based on the specifications in column (5) of Table 2

OUTLINE

1. Data and Basic Facts
2. Model
3. Empirical Strategy
4. Results
5. **Aggregate Implications**
6. Extensions

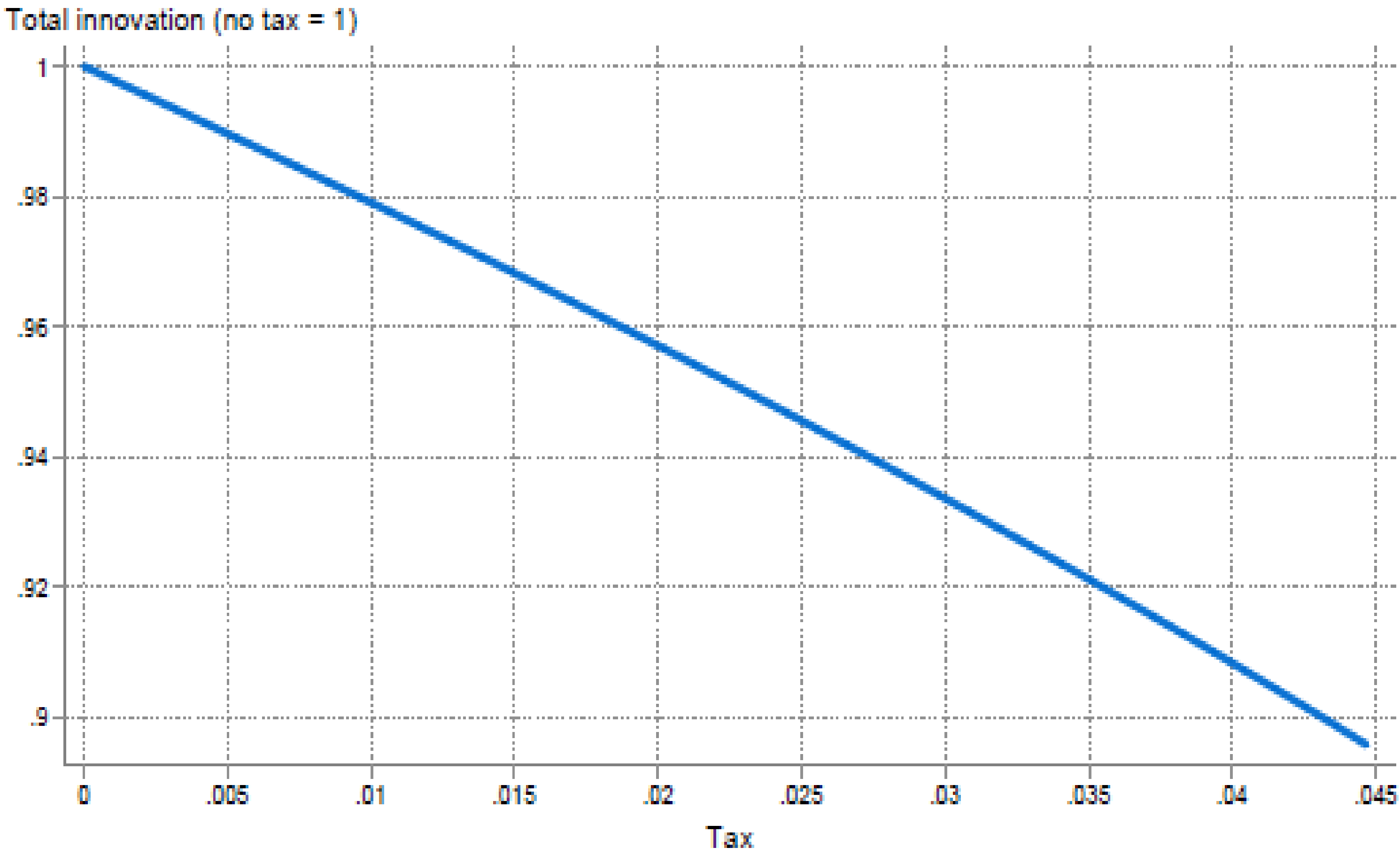
Aggregate Effects

- So far, checked the qualitative implications of the model
- Can also use model to calculate regulation effects on aggregate innovation
- Calibrate parameters from literature, moments form French data, etc.

Quantifying Parameters (Table 3)

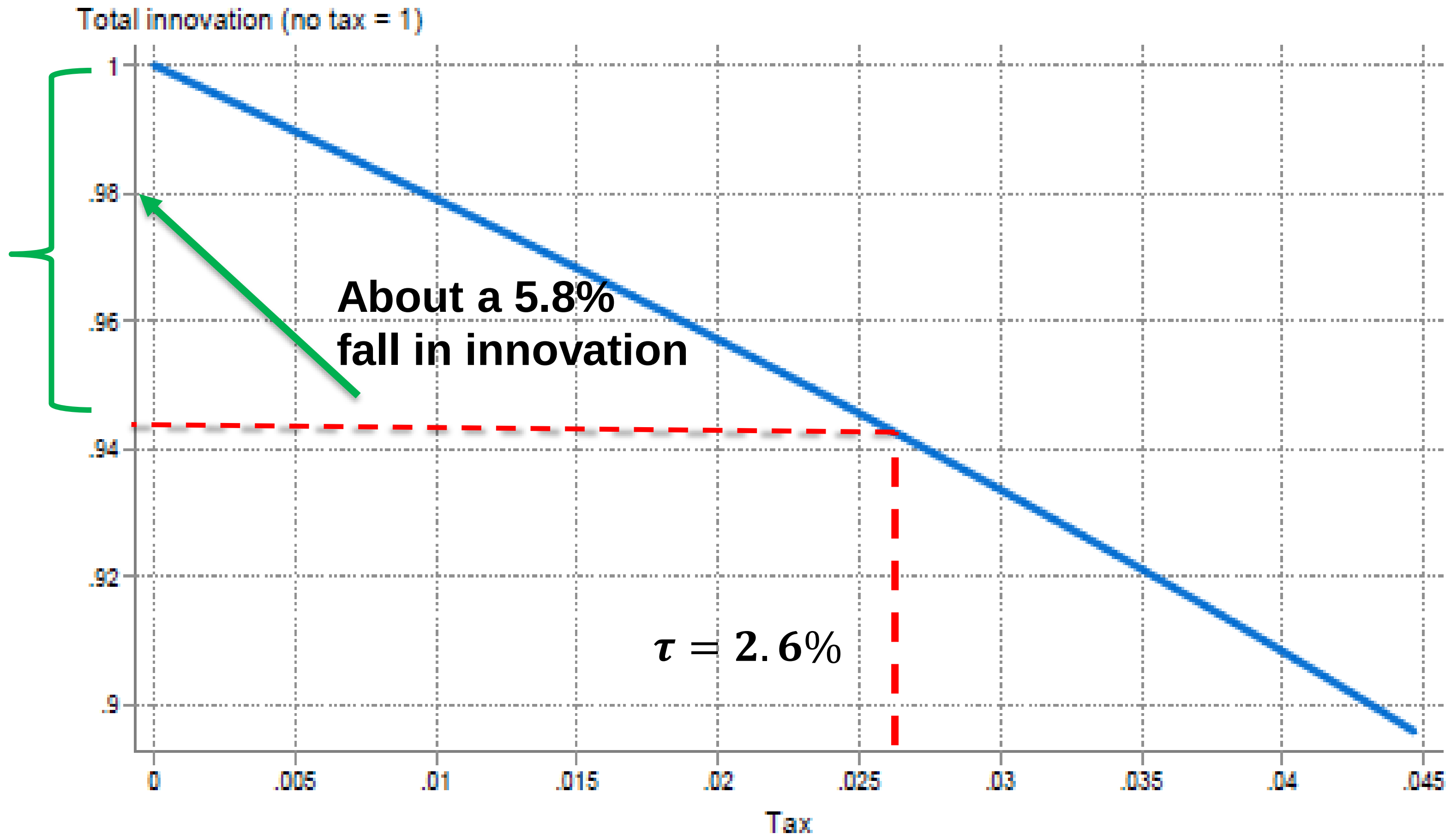
Name	**Parameter**	**Baseline Value (*sensitivity*)**	**Source**
Concavity of the innovation cost function	η	1.5 *(1.3,2.0)*	Dechezlepretre et al (2016). Function of Elasticity of patents with respect to R&D
Innovation step size	γ	1.3 *(1.2,1.5)*	Aghion et al (2019a). Aggregate price-cost mark-up
Discount factor/scale parameter	β/ζ	1.66	Long-run growth rate of the French economy
Regulatory implicit tax	τ	*0.026* *(0.01,0.05)*	Fall in slope of innovation-firm size relationship for big firms (after threshold) compared to small firms (given η)
Output adjusted wage	ω	0.22 *(0.19,0.25)*	Firm size distribution (slope of power law steeper in log-log space when ω larger)

Aggregate Innovation falls by about 5.8% (estimated tax of 2.6%)



Note: Model uses parameters as estimated in Table 3.

Aggregate Innovation falls by about 5.8% (estimated tax of 2.6%)



Note: Model uses parameters as estimated in Table 3. In sensitivity tests range of innovation losses are between 1.3% and 10.1%.

Decomposing aggregate effects (shift share relative to unregulated economy, *Z(τ=0)*

$$Z(\tau) - Z(0) = \sum_{n>0} \left(Z(n,\tau) - Z(n,0)\right)\mu(n,0)$$

Lower firm innovation (evaluated at unregulated firm size distribution)

$$+ \sum_{n>0} \left(\mu(n,\tau) - \mu(n,0)\right)Z(n,0)$$

Shift in firm size (evaluated at unregulated firm innovation)

$$+ \sum_{n>0} \left(\mu(n,\tau) - \mu(n,0)\right)\left(Z(n,\tau) - Z(n,0)\right)$$

Interaction

$$+ z_e(\tau) - z_e(0),$$

Entry

80% of the aggregate effect is the first row: lower innovation by incumbent given firm size distribution

Tab 4: Sensitivity of aggregate innovation losses to changes in assumptions over parameters

Robustness	Loss in total innovation
Panel A: Baseline (full sample)	5.79%
1. $\gamma = 1.2$	5.77%
2. $\gamma = 1.50$	5.82%
3. $\eta = 2$	2.89%
4. $\eta = 1.3$	9.23%
5. $\omega = 0.19$	5.74%
6. $\omega = 0.25$	5.81%
7. $\beta/\zeta = 1.40$	5.79%
8. $\beta/\zeta = 1.90$	5.78%
9. τ	
Percentile 75^{th} ($\tau = 0.046$)	10.53%
Percentile 25^{th} ($\tau = 0.006$)	1.28%

Notes: baseline uses parameter values: ($\eta = 1.5$, $\gamma = 1.3$, $\tau = 0.026$, $\beta/\zeta = 1.66$ and $\omega = 0.22$), see Table 3. In the robustness where γ, η, ω or β/ζ are changed, we keep τ as in the baseline. Line 9 reports the 25^{th} and 75^{th} percentile for the loss of innovation in a sample computed from 100,000 independent draws of τ from two normal distribution. The corresponding value of τ and β/ζ are computed as an average for each percentile. Lines 10-11 report the loss in total innovation when the sample is restricted to exporting manufacturing firms and Line 11 assumes a value of τ as computed using the alternative calibration presented in Section 4.2.3.

Note: Table D3 shows variety of empirically estimating τ (0.012 to 0.050) generating innovation loss of between 2.6% and 10.9%)

Tab 4: Sensitivity of aggregate innovation losses to changes in assumptions over parameters

Robustness	Loss in total innovation
Panel A: Baseline (full sample)	5.79%
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7. $\beta/\zeta = 1.40$	5.79%
8. $\beta/\zeta = 1.90$	5.78%
9. τ	
Percentile 75^{th} ($\tau = 0.046$)	10.53%
Percentile 25^{th} ($\tau = 0.006$)	1.28%
Panel B: Sub-sample of Exporting manufacturing firms	
10. Static estimation ($\tau = 0.062$)	14.69%
11. Using dynamic model ($\tau = 0.060$)	14.20%

Notes: baseline uses parameter values: ($\eta = 1.5$, $\gamma = 1.3$, $\tau = 0.026$, $\beta/\zeta = 1.66$ and $\omega = 0.22$), see Table 3. In the robustness where γ, η, ω or β/ζ are changed, we keep τ as in the baseline. Line 9 reports the 25^{th} and 75^{th} percentile for the loss of innovation in a sample computed from 100,000 independent draws of τ from two normal distribution. The corresponding value of τ and β/ζ are computed as an average for each percentile. Lines 10-11 report the loss in total innovation when the sample is restricted to exporting manufacturing firms and Line 11 assumes a value of τ as computed using the alternative calibration presented in Section 4.2.3.

Welfare

- Cost of regulation is less innovation and growth
- But a **benefit** of regulation is less resources on R&D, so more output can be consumed
- Regulation might “tax” wasteful, business stealing R&D, so might theoretically be welfare enhancing
- Most empirical studies suggest “too little” R&D (e.g. Jones & Summers, 2022; Lucking et al, 2020; Bloom et al, 2013)
- But what about our context?

Welfare

- Assume planner maximizes utility of representative household with Utility

$$U = \sum_{t>0} \beta^t log C_t$$

- Compare welfare in unregulated vs regulated economy (with equivalent tax of *τ*)

$$\Delta U \equiv U(\tau) - U(0)$$
$$= \log\left(\frac{1+g(\tau)}{1+g(0)}\right)\frac{\beta}{(1-\beta)^2} + \log\left(\frac{1-R(\tau)}{1-R(0)}\right)\frac{1}{1-\beta} + \log\left(\frac{Y_0(\tau)}{Y_0(0)}\right)\frac{1}{1-\beta},$$

Lower growth under regulation

R&D saving

Loss of static efficiency

Welfare

- Assume planner maximizes utility of representative household with Utility $U = \sum_{t>0} \beta^t log C_t$
- Compare welfare in unregulated vs regulated economy (with equivalent tax of *τ*)

$$\Delta U \equiv U(\tau) - U(0)$$
$$= \log\left(\frac{1+g(\tau)}{1+g(0)}\right)\frac{\beta}{(1-\beta)^2} + \log\left(\frac{1-R(\tau)}{1-R(0)}\right)\frac{1}{1-\beta} + \log\left(\frac{Y_0(\tau)}{Y_0(0)}\right)\frac{1}{1-\beta},$$

Lower growth under regulation | **R&D saving** | **Loss of static efficiency**

- Net effect is **2.3%** consumption equivalent loss
- First term dominates: 5.8% slower growth
- This is <u>lower bound</u>, as we know static effect (3rd term) is negative, but hard to calculate without more assumptions (e.g. 1.3 to 3.4% in Garicano et al, 2016).

OUTLINE

1. Data and Basic Facts

2. Model

3. Empirical Strategy

4. Results & Aggregate Implications

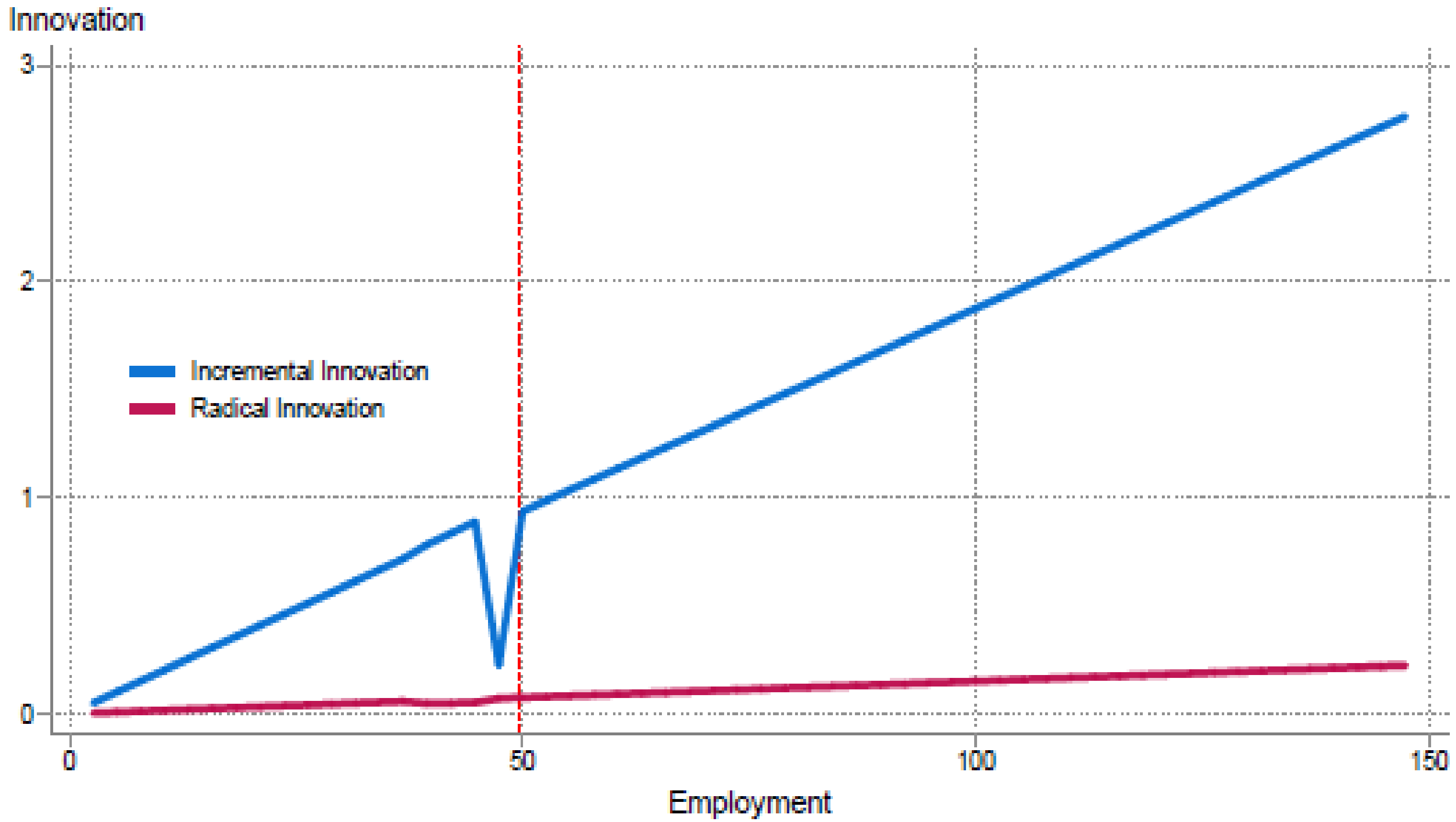
5. **Extensions**
   - **Incremental & radical innovation**
   - Empirical robustness
   - Generalizing theory

Extension to two types of innovation: incremental and radical

- We extend the model to allow for two types of innovation
  - Regular "incremental" innovation as before
  - Radical ("big") innovation which allows the firm to increase by $k>1$ product lines, but is more costly

- Intuitively, if a firm is going to innovate, then those just below the threshold will much prefer radical to incremental innovation

Figure 7: Firm Innovation by employment size for incremental and radical innovations.

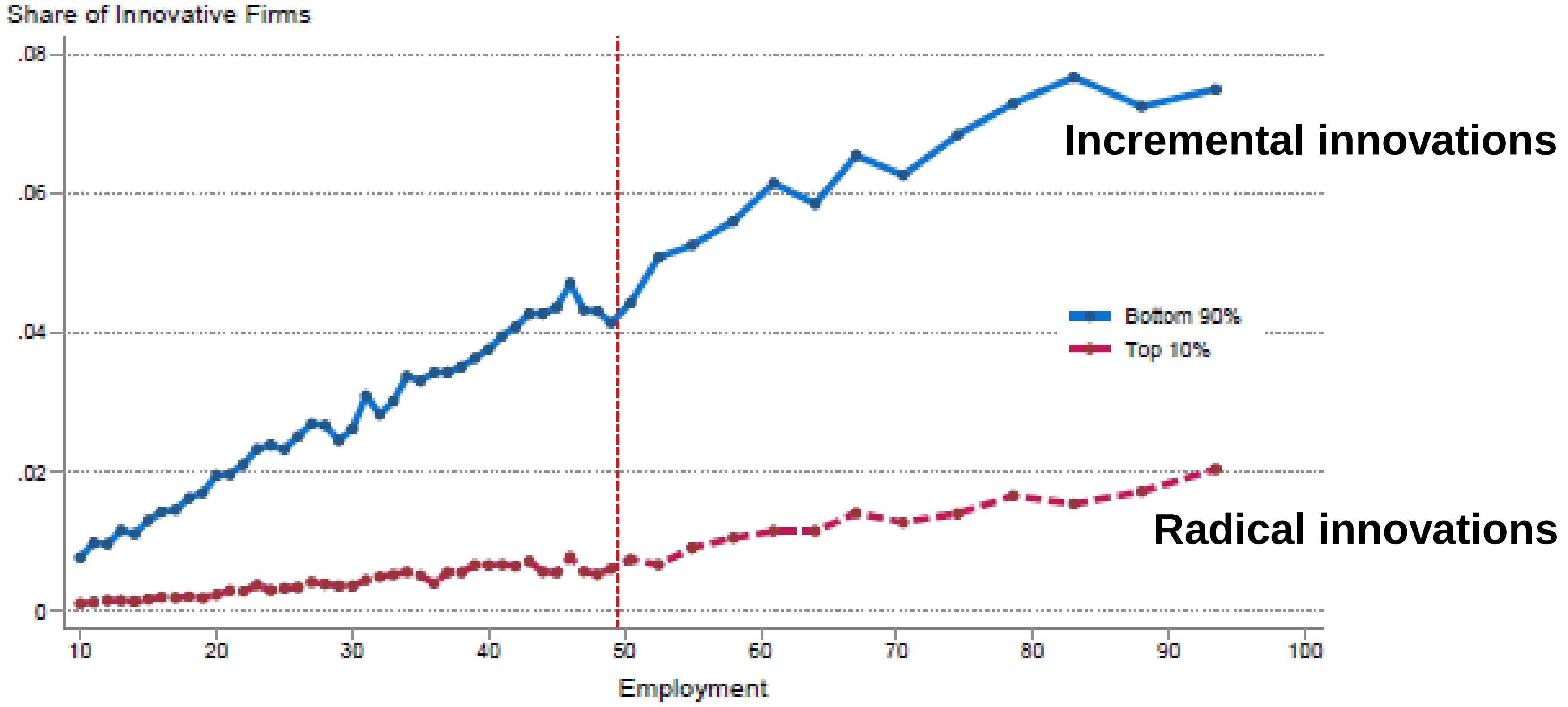


Notes: This is total incremental innovation $z(n)n$ (blue solid line) and total radical innovation $u(n)n$ (red dashed line) for firms of n lines against employment in the extension where firms can choose between two types of innovations. We used the same parameter values as in Figure 1 and $k = 4$ and $\alpha =$.

Measuring Types of innovation

- Future citations (by technology class-year of patent application)
  - Thresholds (e.g. top 10% “radical” vs. bottom 90% “incremental”)

Fig 8: Valley only for low quality ("incremental") innovators not high quality ("radical") innovators (top 10% of future citations distribution)



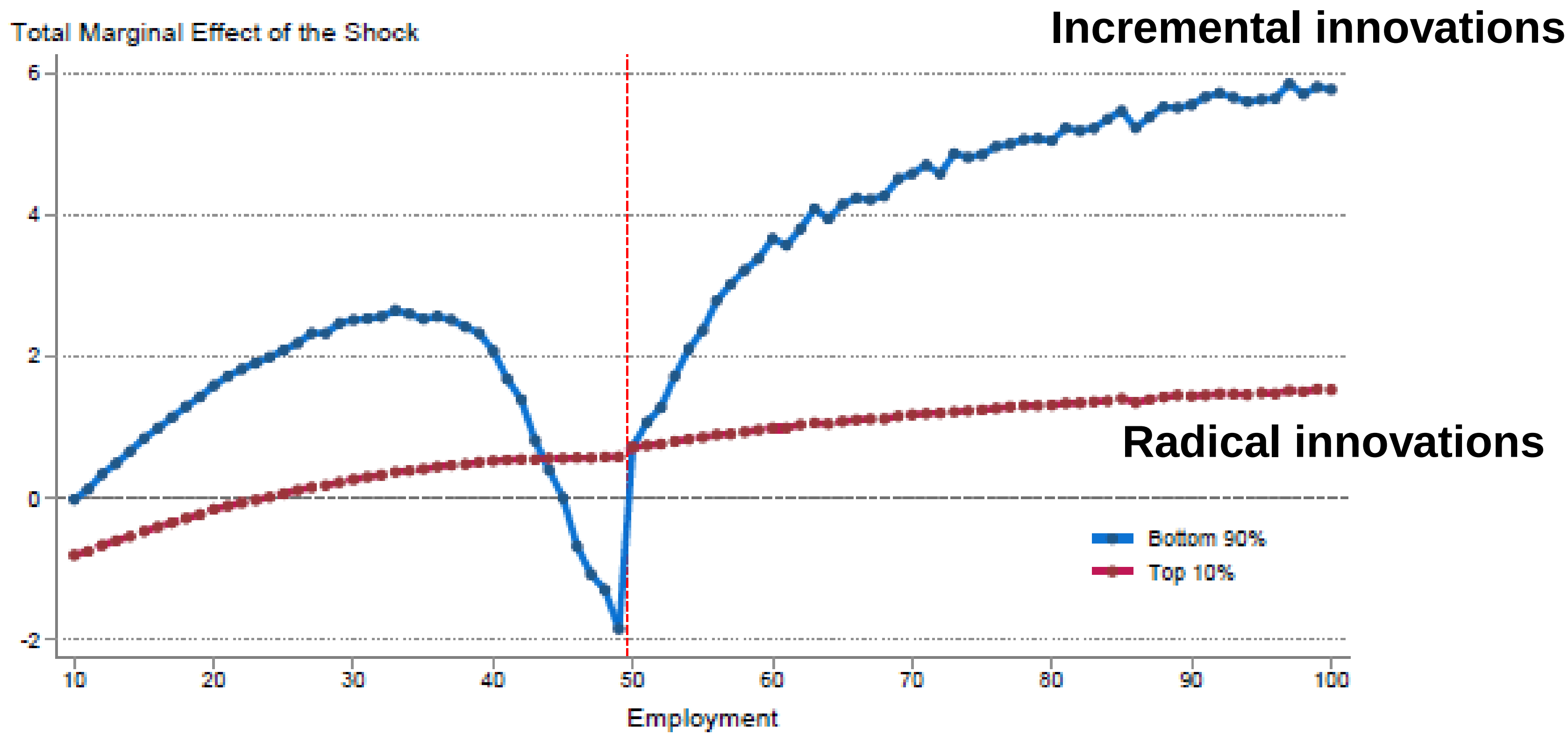
Notes: Share of firms with at least one priority patent in the top 10% most cited (dashed line) and the share of firms with at least one priority patent among the bottom 90% most cited in the year (solid line). All observations are pooled together. Employment bins have been aggregated so as to include at least 10,000 firms. The sample is based on all firms with initial employment between 10 and 100 (82,347 firms and 1,658,762 observations, see Panel A of Table 1).

Tab 5: Weaker effect of demand shocks below threshold only exist for incremental innovation

Quality	Top 10%	Top 15%	Top 25%	Bottom 75%	Bottom 85%	Bottom 90%
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
$Shock_{t-2} \times L^{\star}_{t-2}$	-0.210	0.961	-0.828	-4.745	-6.014**	-6.158**
	(0.846)	(0.843)	(0.938)	(2.801)	(2.689)	(2.549)
$L^{\star}_{t-2}$	-0.043	-0.019	-0.046	0.162	0.093	0.070
	(0.040)	(0.068)	(0.075)	(0.124)	(0.104)	(0.109)
$Shock_{t-2}$	-1.499	-2.198	-5.568**	-1.809	-3.901	-3.739
	(1.083)	(1.536)	(2.118)	(2.929)	(2.520)	(2.321)
$log(L)_{t-2}$	0.017	-0.010	-0.041	-0.018	-0.044	-0.060*
	(0.015)	(0.024)	(0.031)	(0.023)	(0.034)	(0.034)
$Shock_{t-2} \times log(L)_{t-2}$	0.508	0.715	1.786**	0.913	1.535*	1.495*
	(0.338)	(0.475)	(0.673)	(1.026)	(0.861)	(0.803)
Fixed Effects						
Sector×Year	✓	✓	✓	✓	✓	✓
Number Obs.	142,474	142,474	142,474	142,474	142,474	142,474

Notes: estimation results of the same model as in column 5 of Table 2. The dependent variable is the Davis and Haltiwanger (1992) growth rate in the number of priority patent applications between $t-1$ and t, restricting to the top 10% most cited in the year (column 1), the top 15% most cited in the year (column 2), the top 25% most cited in the year (column 3), the bottom 85% most cited in the year (column 4), the bottom 75% most cited in the year (column 5) and the bottom 90% most cited in the year (column 6). All models include a 2-digit NACE sector interacted with a year fixed effect and a time fixed effect interacted with the initial level of export intensity. Estimation period: 1998-2007 . Standard errors are clustered at the 2-digit NACE sector level. ***, ** and * indicate p-value below 0.01, 0.05 and 0.1 respectively.

Fig 9: Implied Marginal effect of demand shocks on innovation by firm size



Notes: marginal effect of a shock at different level of employment, based on the model in column 1 and 6 of Table 5. Marginal effect is calculated on top 10% and bottom 90% most cited patents.

Note: These are based on the estimates in columns (1) and (6) of Table 5

Measuring Types of innovation

- Future citations (by technology class-year of patent application)

- Also use natural language processing via Google Patent Embeddings (Srebrovic, 2019):
  - *Novelty* following Kelly et al (2021).
  - *Automation* (Mann & Puttman, 2018; Webb, 2020)
  - *Process Innovation* (Belenzon et al., 2020)

OUTLINE

1. Data and Basic Facts

2. Model

3. Empirical Strategy

4. Results & & Aggregate Implications

5. **Extensions**
   - Incremental & radical innovation
   - **Empirical robustness**
   - Generalizing theory: R&D as scientists; infinitely lived agents

Robustness

- **Add firm FE (firm trends); Tab 2 col (7)**
- **Add non-manufacturing. Tab 2 col (8)**
- **Add employment growth. Tab 2 col (9)**

Tab 2: Demand shocks have weaker effects on innovation just below the regulatory threshold

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$Shock_{t-2} \times L^*_{t-2}$				-5.018**	-6.135***	-5.555**	-6.560**	-3.682**	-6.057**
				(2.229)	(2.195)	(2.264)	(2.758)	(1.778)	(2.350)
L^*_{t-2}				0.043	0.077	0.069	-0.011	0.081	0.068
				(0.104)	(0.129)	(0.107)	(0.185)	(0.054)	(0.109)
$Shock_{t-2}$	1.104**	-4.476**	7.397	1.418**	-5.293**	6.130	-5.547**	-3.292**	-5.214**
	(0.488)	(2.034)	(6.364)	(0.512)	(2.483)	(6.258)	(2.396)	(1.250)	(2.059)
$log(L)_{t-2}$		-0.049	-0.017		-0.057	-0.026	-0.111	-0.036	-0.057
		(0.038)	(0.162)		(0.036)	(0.162)	(0.189)	(0.024)	(0.034)
$Shock_{t-2} \times log(L)_{t-2}$		1.723**	-6.061		2.025**	-5.305	2.123**	1.209***	1.994***
		(0.642)	(4.603)		(0.816)	(4.526)	(0.807)	(0.441)	(0.667)
$log(L)^2_{t-2}$			-0.005			-0.005			
			(0.029)			(0.029)			
$Shock_{t-2} \times log(L)^2_{t-2}$			1.097			1.175			
			(0.759)			(0.749)			
$\Delta log(L)_{t-2}$									0.050
									(0.225)
Fixed Effects									
Sector×Year	✓	✓	✓	✓	✓	✓	✓	✓	✓
Firm							✓		
Number Obs.	142,474	142,474	142,474	142,474	142,474	142,474	142,474	330,063	142,396

Note: SE clustered by 3 digit industry. All models include 3 digit industry dummies and year effects

Robustness

- Add firm FE (firm trends); Tab 2 col (7)
- Add non-manufacturing. Tab 2 col (8)
- Add employment growth. Tab 2 col (9)
- **Placebo looking at nonlinearities for 14 other size thresholds in bandwidths of 5 employees 10-14,…,75-79. Only find effect for the 45-49 below threshold. Tab D1**
- **Alternative functional form of dep. var. to DHS: IHS; log differences, normalize on pre-sample patents. Tab D2**
- **Instead of using bandwidth of 10 to 100 employees use [10,500]; [0,100]. Table D2**
- **Restrict to 1994 exporters; include non-exporters. Tab D2**
- **Alternative timing to t-2 shock. Tab D2**
- **Tests of Bartik assumptions (e.g. Borusyak et al, 2020)**

OUTLINE

1. Data and Basic Facts

2. Model

3. Empirical Strategy

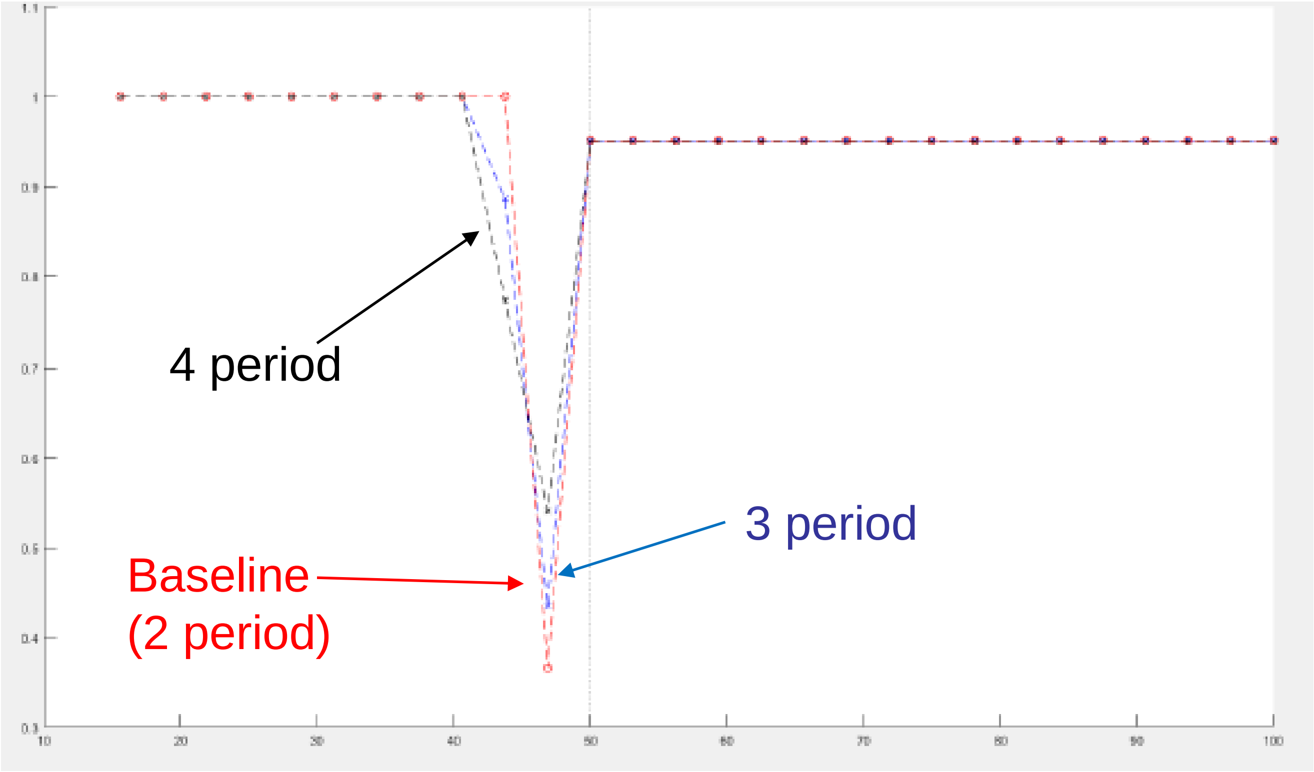
4. Results & Aggregate Implications

5. **Extensions**
    - Incremental & radical innovation
    - Empirical robustness
    - **Generalizing theory: longer lived agents; R&D as scientists**

Longer lived agents

- Baseline model allows firms to live forever, but owners live for one period
- Extend this to multiple periods (up to infinitely lived). Consider one extra period, calibrate, then two extra periods, etc.
- Flattens out valley (a bit), but little difference in terms of innovation and welfare loss.

Fig C3: Multi-period lived owner model (R&D intensity per line) relative to unregulated economy



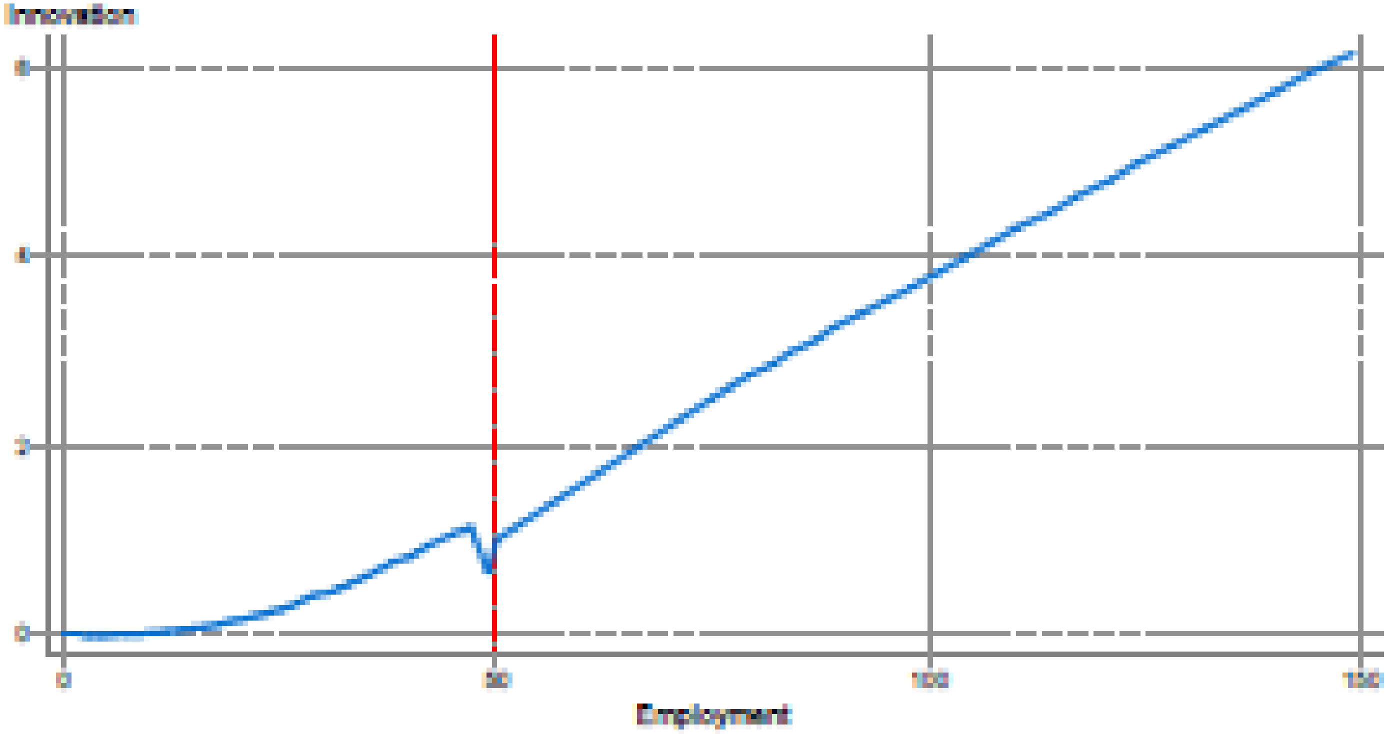
Notes: Innovation Valley widens, but gets shallower. New quantitative estimation suggests similar losses to baseline. “Grandfathering” model

R&D as scientists

- Baseline is "Lab Equipment" model, where R&D is taken in units of final output. Means wage constant over time and GDP growth taken in the form of shareholder profits
- Extension where R&D is scientists, so agents can choose to work in production or R&D sector
- Firm size is now affected by amount of current innovation unlike baseline model (depends only on just past innov)
- Employment threshold depends on #products <u>and</u> R&D.
- No longer a closed form: Model must be solved numerically. Main results go through, but regulation now also depresses equilibrium wages

Fig C4: Innovation and Firm size in the R&D as scientist model

(a) Innovation



Conclusions - Summary

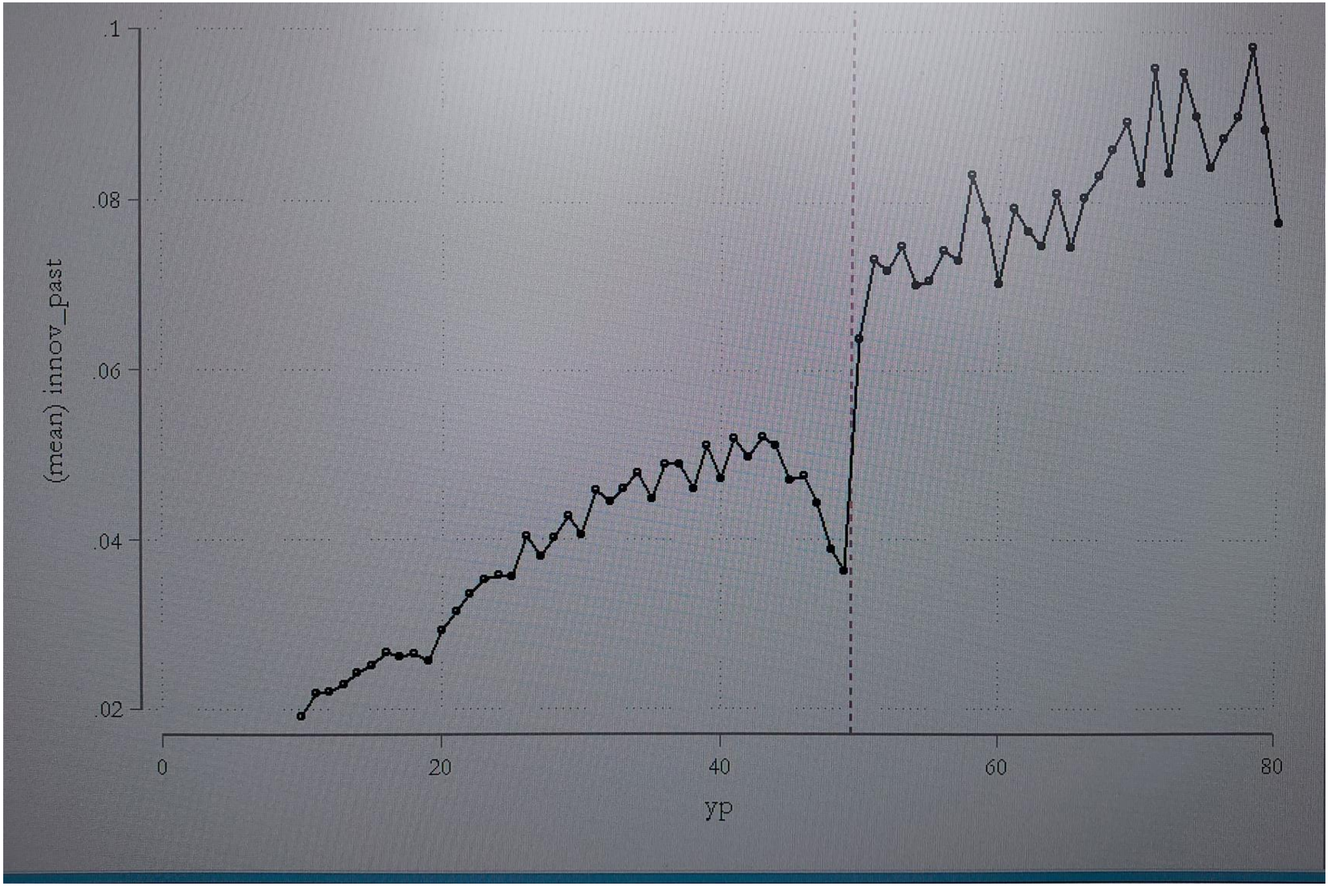
- Regulation has dynamic effects by affecting innovation incentives
- Theoretically and empirically, prospect of regulatory costs discourages innovation for firms just below the threshold (& large firms do less because of implicit tax on growth)
  - Evidence for this in static and dynamic analysis
- Aggregate effects look important: around 5.8% fall in innovation (2.3% lower bound on welfare loss)
- But both in cross section and using exogenous demand shocks in panel, the negative impact is confined to incremental (rather than radical) innovations

Conclusions - Discussion

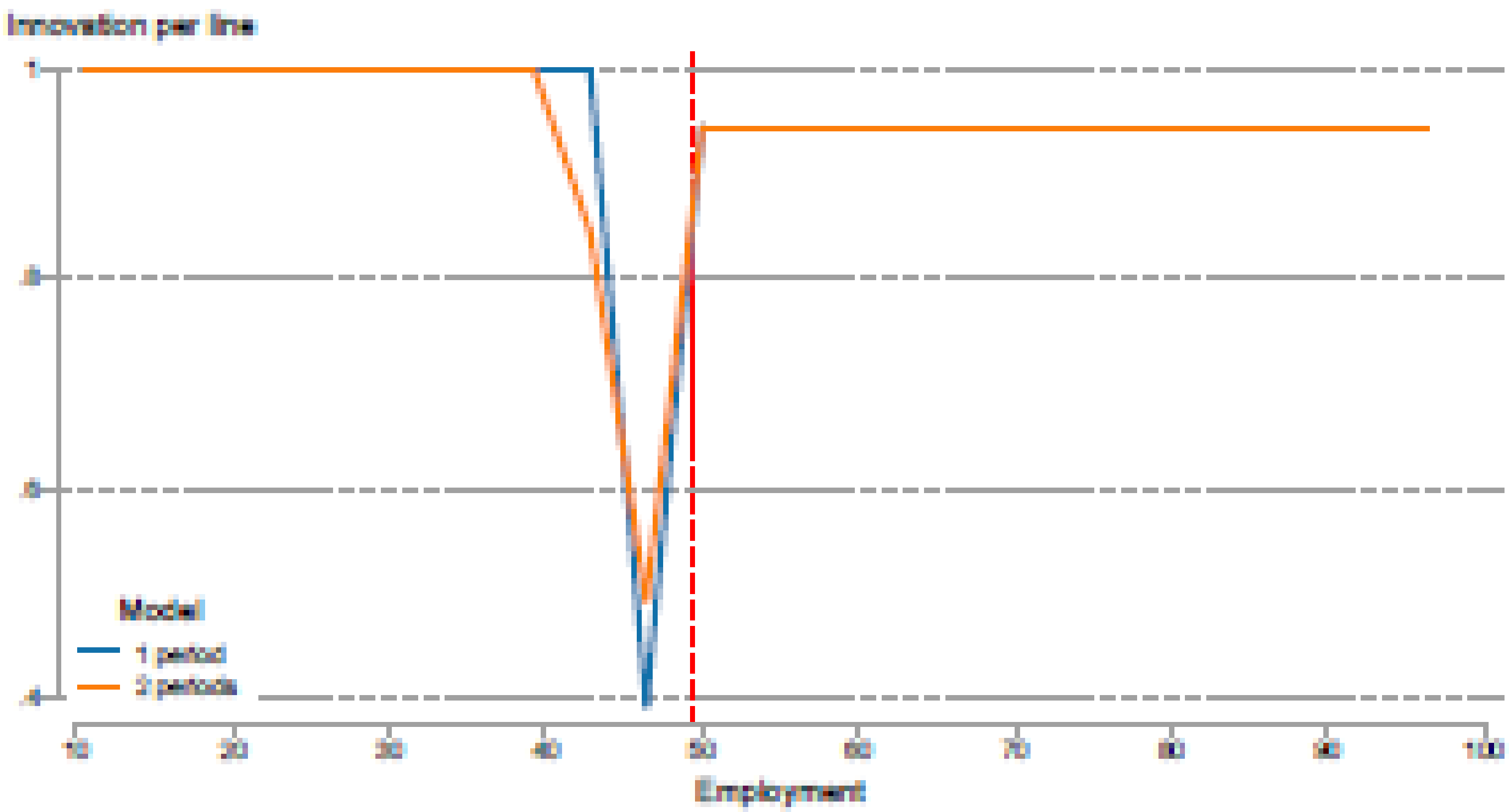
- We have not quantified **benefits** of regulation in terms of insurance, security, investment in firm specific skills
  - Places a bound on these benefits.
  - And no wage change around threshold
- Does it matter that incremental innovation is discouraged
  - Are main market failures only for radical innovation? (estimating spillover effects for incremental vs. radical innovation using production functions)
- Methods: Beyond calibration to structural estimation
- Add in ex ante heterogeneity (e.g. Acemoglu et al, 2018; Garicano et al, 2016)

Thanks!

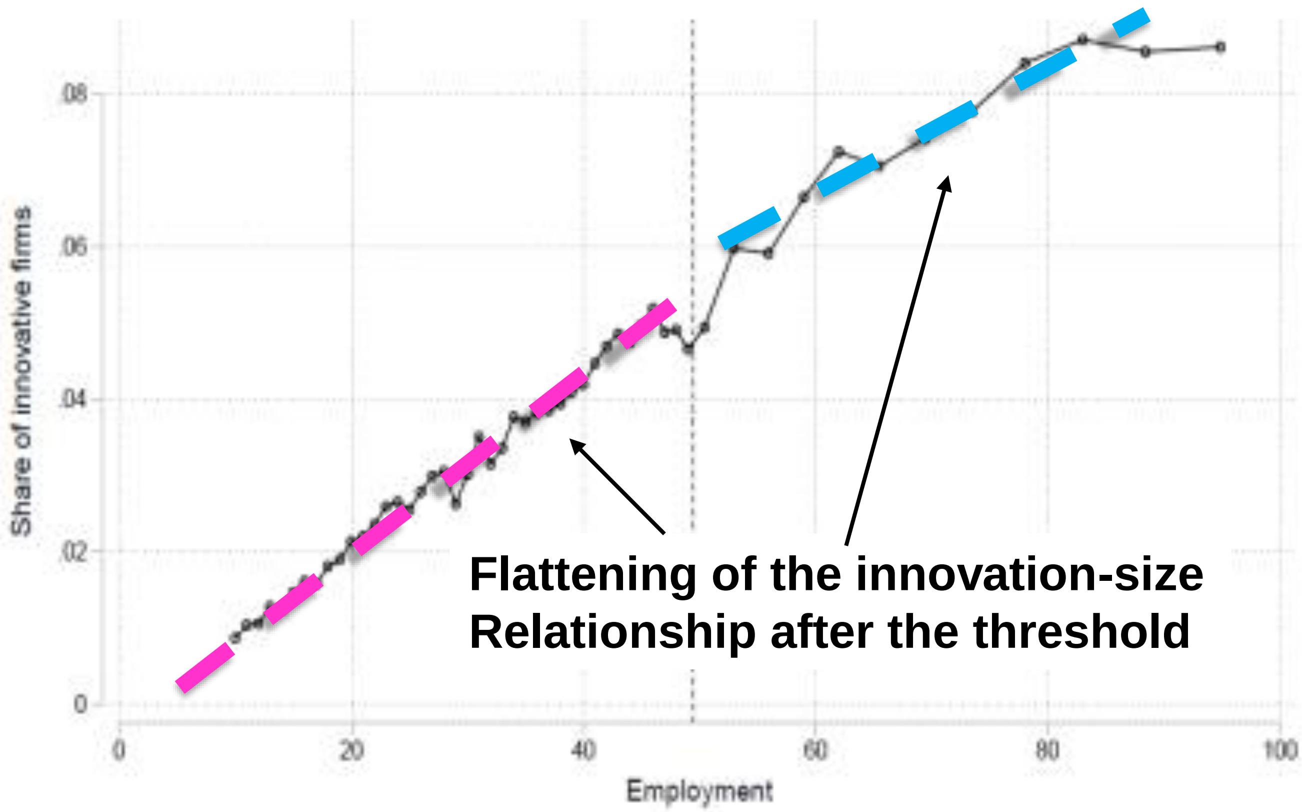
Share of innovative firms by firm size: Using indictor for whether a firm performs R&D



(a) Innovation



Share of innovative firms at different firm employment levels



Notes: share of firms with at least one priority patent against employment at t. All observations are pooled together. Employment bins have been aggregated so as to include at least 10,000 firms. The sample is based on all firms with initial employment between 10 and 100 (154,582 firms and 1,439,396 observations).

Table D3: Alternative estimation of τ

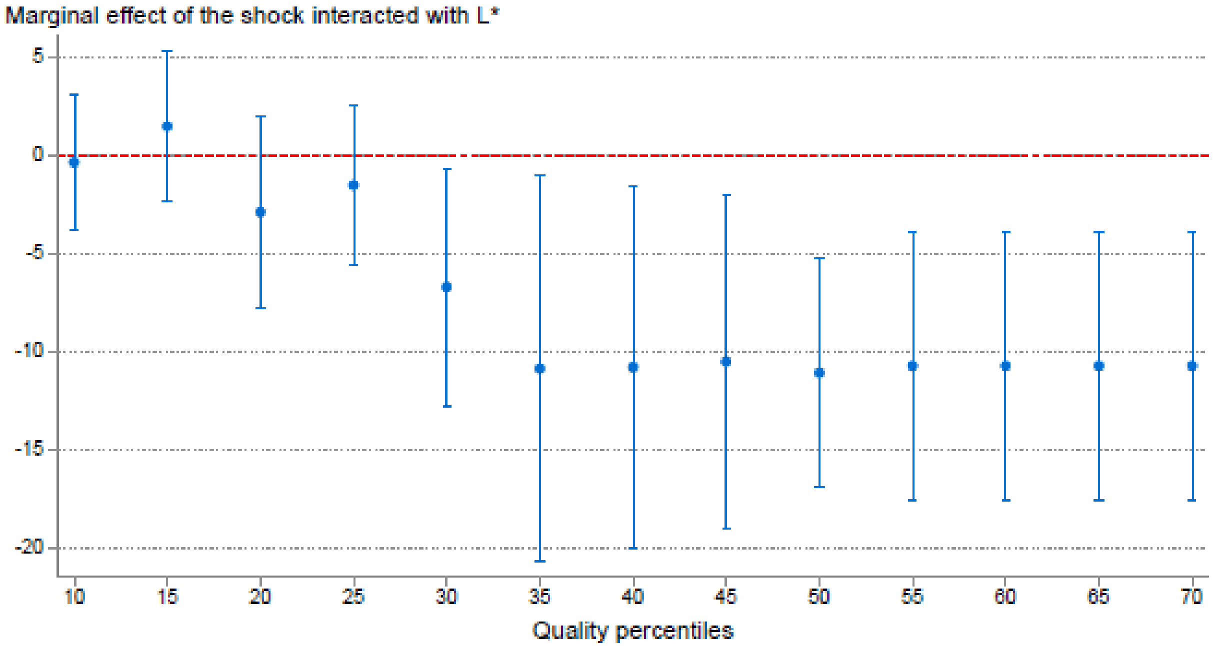
Observations	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Employment binned					Firm level	
τ	2.6%	3.7%	1.3%	1.2%	5.0%	3.8%	4.0%
Total Innovation loss (%)	5.79	8.30	2.79	2.57	10.94	8.49	8.87
Welfare loss (% of C equivalent)	2.27	3.25	1.15	1.06	4.45	3.46	3.62

Notes: This Table presents alternative OLS estimates of parameter τ based on the innovation-employment relationship of equation (4). Columns(1)-(5) bin observations at the employment level (one observation per level of employment) τ is computed as the ratio of two slope, respectively for firms between 10 and 45 employees and for firms between 50 and 100 (except column (2) which extends this to 250). The left-hand side variable is the log of the total number of patents computed as a five year average before t to which we add 1 for columns (1), (2) and (3). Column (4) uses the number of patents in level (as opposed to log) and column (5) the average of a dummy variable equal to 1 if the number of patents in the past five years is non-zero (which is equivalent to the share of firms with at least one patent at a specific level of employment). Columns (6) and (7) use the panel of firm-year (1,737,476 observations) to estimate the coefficient on the 2 year lag of employment on the log of the number of patents at $t+1$. Column (6) includes a 2-digit sector fixed effect and year fixed effects and column (7) includes sector-year fixed effects. Each estimation includes dummies for each employment level between 46 and 49.

Ex ante Heterogeneity?

- We have ex post heterogeneity in productivity and size because of history. Firms who innovate grow, those who do not or are displaced shrink and die.
- Stochastic process interacts with environment (especially regulation) to give heterogeneous productivity & size. But we could also give firms ex ante heterogeneity. Examples:
  - Garicano et al (2016) have continuous managerial ability distribution a la Lucas (1978) but add regulatory tax
  - Acemoglu et al (2018) have 2 types of firms born with (i) high and (ii) low R&D productivity. Every period a high firm could become low randomly. Rich dynamics, but no tax.

Figure D4: Response to the Demand shock of patents of different quality



Notes: 95% confidence intervals around the estimated coefficient δ in equation (7). Each line corresponds to a separate estimation, where the dependent variable has been redefined by restricting to patents among the x% more cited in the year, with x equal to 10, 15 etc... up to 70. Note that the 65^{th} percentile threshold correspond to 0-citation patent and we include all patents for quality percentiles above 65. The estimated model is the same as in column 5 of Table 2.

Alternative measures of patent type/quality

- “Novelty” using text-to-data ML approach of Kelly et al (2018). Are words used in patent description different from state of art in technology-class cohort?
  - Similar results to top citations

- “Automation” patents (Mann and Püttmann, 2018) or process innovations (Arora, Belenzon, Cohen and Lee, 2020)
  - Regulation stronger negative effect on non-automation and non-process innovation

Infinitely Lived Agents

- Allowing agents to be infinite lived (or bequest-driven)
- Value function

$$V(n) = \max_{z \geq 0} \left\{ n\pi(n)y - \zeta z^{\eta} n y + \frac{1}{1+r} \mathbb{E}\left[V(n')\right] \right\}$$

- Let ρ = (1 - β)/β and W(n) = βV(n)/y
- Bellman Equation

$$\rho \frac{W(n)}{n} = \max_{z \geq 0} \left\{ \pi(n) - \zeta z^{\eta} + z\left(W(n+1) - W(n)\right) + x\left(W(n-1) - W(n)\right) \right\}.$$

- Unlike baseline equation, no closed form for W(n) because π(n) now varies with n. But can still solve model numerically
- Basic results go through, just smoothed a bit more from the discontinuity