The Impact of Regulation on Innovation

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CEPR Conference on Globalization, Technology and Firms:  
Labor Market Outcomes CEPR  
November 19th 2020
Introduction

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

• We develop a heterogeneous firm macro framework with endogenous R&D to study how regulation affects joint distribution of firm innovation & size.
France has tough Employment Protection Laws, but do these really cause economic problems?

Source: OECD (2019)
Reform Ain’t Easy

France strikes over pension
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 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 DOESN’T 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
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
  - **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 \(~5.4\%) 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 (\(~2.2\%)\)

• **Caveat**: 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
• **Labor Regulation & Innovation:** Acharya et al (2013a,b); Griffith and Macartney (2014); Garcia-Vega et al (2019); Mukoyama & Osotimehin (2019)


• **Market size & innovation:** Acemoglu & Linn (2004); Schmookler (1966); Shleifer (1986); Barlevy (2007); Aghion 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 (2019); Akcigit & Stantcheva (2020)
1. Data and Basic Facts

2. Model

3. Empirical Strategy

4. Results

5. Aggregate Implications

6. Extensions
Data

  - Mandatory fiscal returns of all firms ("FICUS").
- 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 threshold & flattening slope after

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).
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Basic Framework

- 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 choice (& knowledge stock reflected in in size, $n_i$).
Basic Framework

- Continuum of product lines/varieties, $n_i$, 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 choice (& knowledge stock reflected in in size, $n_i$).
- Each firm lines 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).
- For expositional reasons, do simple model of 2 period owners (firms can live forever). Appendix C does infinitely lived agent version.
Productivity level

Firm $i$

product line $j$
Firm $i$ produces single line ($j=4$) with productivity $A_{i4}$.
Firm $i'$ has 3 lines ($j = 1,2,3$) with productivities $(A_{i'1}, A_{i'2}, A_{i'3})$. 

Productivity on line $A_j$:

- $j = 1$: Productivity $A_{i'1}$
- $j = 2$: Productivity $A_{i'2}$
- $j = 3$: Productivity $A_{i'3}$
- $j = 4$: Productivity $A_{i}^*$ (a 1 line firm)
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 $j = 3$

Productivity on line $A_j$

$A_{i3} = \gamma A_{i'3}$

- $j = 1$
- $j = 2$
- $j = 3$
- $j = 4$

Firm $i$ (now a $n=2$ line firm)

Firm $i'$ (now a $n=2$ line firm)
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, $\tau$

• The firm chooses $z$ (R&D per line) to maximize NPV:

\[
\pi(n) + \beta z[(n + 1)\pi(n + 1) - n\pi(n)] + \beta x[(n - 1)\pi(n - 1) - n\pi(n)] - \zeta z^n
\]

\[
\text{Discounted Incremental profit from innovating (prob = z) & producing n+1 lines}
\]

\[
\text{Discounted Incremental loss from being replaced (prob = x) by another firm & producing n-1 lines}
\]

\[
\text{R&D cost}
\]

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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\end{align*}
\]

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 per line, \( z(n) = \frac{Z}{n} \): Three Regimes

<table>
<thead>
<tr>
<th>Category</th>
<th>Expression</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Small firms</strong></td>
<td>( \frac{1}{\gamma^{\eta-1}} \left( \frac{\beta (\gamma - 1)}{\gamma \zeta \eta} \right) )</td>
<td>( n &lt; \bar{n} - 1 )</td>
</tr>
<tr>
<td><strong>Medium firms</strong></td>
<td>( \frac{1}{\gamma^{\eta-1}} \left( \frac{\beta (\gamma - 1)(1 - \tau \bar{n})}{\gamma \zeta \eta} \right) )</td>
<td>( n = \bar{n} - 1 )</td>
</tr>
<tr>
<td><strong>Big firms</strong></td>
<td>( \frac{1}{\gamma^{\eta-1}} \left( \frac{\beta (\gamma - 1)(1 - \tau)}{\gamma \zeta \eta} \right) )</td>
<td>( n \geq \bar{n} )</td>
</tr>
</tbody>
</table>

\( \bar{n} \) is the regulatory threshold
Firm’s optimal innovation per line, $z(n) = (Z/n)$:

**Three Regimes**

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

$\zeta, \eta$ are parameters in R&D cost function:
- bigger $\eta$ means lower innovation-R&D elasticity
Firm’s optimal innovation per line, \( z(n) = (Z/n) \):

Three Regimes

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

**Medium firms**  
Just below threshold  
\[
\left( \frac{\beta (\gamma - 1)(1 - \tau \bar{n})}{\gamma \zeta \eta} \right)^{\frac{1}{\eta - 1}} \text{ if } n = \bar{n} - 1
\]

**Big firms**  
above threshold  
\[
\left( \frac{\beta (\gamma - 1)(1 - \tau)}{\gamma \zeta \eta} \right)^{\frac{1}{\eta - 1}} \text{ if } n \geq \bar{n}
\]

\( \bar{n} \) is the regulatory threshold
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/(γω)) 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

Innovation Valley:
Loss to left of threshold

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Fig 3(a): 2 types of firm-level Innovation losses

Innovation Valley:
Loss to left of threshold

Big firms do less innovation because of regulation tax (flattening the slope)

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

Employment distribution

Regulated Economy

Unregulated economy

With tax
Without Tax
Tab 4: Putting it all together: aggregate Loss of Innovation as a function of the 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 ($\tau$). For example, if $\tau = 0.02$, aggregate innovation is 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 $\tau$. 
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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 $\omega_{i,s,j,t_0}$.
- We interact this weight ($\omega_{i,s,j,t_0}$) with growth in imports ($\tilde{I}_{s,j,t}$) of this country-product (excluding France), to construct the IV:

$$\Delta S_{it} = \sum_{s,j \in \Omega(i,t_0)} \omega_{i,s,j,t_0} \tilde{I}_{s,j,t}$$
Patent Growth Equation

\[ \Delta Y_{i,t} = \delta (\Delta S_{i,t-2} \cdot L^*_{i,t-2}) + \alpha \Delta S_{i,t-2} + \beta L^*_{i,t-2} \\
+ \gamma [\Delta S_{i,t-2} \cdot P(\log(L_{i,t-2}))] + \psi_{s(i,t)} + \tau_t + \varepsilon_{it} \]

- \( L^* = 1 \) if firm has between 45 and 49 employees & zero otherwise; \( L \) = firm employment;
- \( P(\log(L_{i,t-2})) \) polynomial to flexibly control for size
- \( \psi_{s(i,t)} = \) industry dummies; \( \tau_t = \) year dummies
- **Key Hypothesis is** \( \delta < 0 \): firms increase innovation by less to a positive shock when just below the threshold
- Patent growth in “DHS” form:

\[ \Delta Y_{i,t} = \begin{cases} 
\frac{Y_{t-1} - Y_{t-1}}{Y_t + Y_{t-1}} & \text{if } Y_t + Y_{t-1} > 0 \\
0 & \text{otherwise}
\end{cases} \]
Tab 2: Demand shocks have weaker effects on innovation just below the regulatory threshold

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Shock_{t-2} \times L_{t-2}^*$</td>
<td>-11.910**</td>
<td>-13.924**</td>
<td>-13.135**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(5.806)</td>
<td>(5.880)</td>
<td>(5.874)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$L_{t-2}^*$</td>
<td>0.045</td>
<td>0.066</td>
<td>0.066</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.138)</td>
<td>(0.147)</td>
<td>(0.146)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.172)</td>
<td>(4.173)</td>
<td>(9.728)</td>
<td>(4.185)</td>
<td>(9.652)</td>
<td></td>
</tr>
<tr>
<td>$log(L)_{t-2}$</td>
<td>-0.036</td>
<td>0.012</td>
<td>-0.040</td>
<td>0.008</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.027)</td>
<td>(0.104)</td>
<td>(0.031)</td>
<td>(0.102)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$Shock_{t-2} \times log(L)_{t-2}$</td>
<td>3.270**</td>
<td>-10.853</td>
<td>3.898***</td>
<td>-9.281</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.374)</td>
<td>(7.524)</td>
<td>(1.392)</td>
<td>(7.490)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$log(L)_{t-2}^2$</td>
<td>-0.008</td>
<td></td>
<td></td>
<td>0.156</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.019)</td>
<td></td>
<td></td>
<td>(0.151)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$Shock_{t-2} \times log(L)_{t-2}^2$</td>
<td>2.182*</td>
<td></td>
<td></td>
<td>2.031</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.291)</td>
<td></td>
<td></td>
<td>(1.287)</td>
<td></td>
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</tr>
</tbody>
</table>

Fixed Effects:
- Sector: ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
- Year: ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
- Firm: ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓

Number Obs.: 186,337  186,337  186,337  186,337  186,337  186,337

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
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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)

<table>
<thead>
<tr>
<th>Name</th>
<th>Parameter</th>
<th>Baseline Value (sensitivity)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concavity of the innovation cost function</td>
<td>$\eta$</td>
<td>1.5 (1.3,2.0)</td>
<td>Dechezlepretre et al (2016). Function of Elasticity of patents with respect to R&amp;D</td>
</tr>
<tr>
<td>Innovation step size</td>
<td>$\gamma$</td>
<td>1.3 (1.05,1.5)</td>
<td>Aghion et al (2019a). Aggregate price-cost mark-up</td>
</tr>
<tr>
<td>Discount factor/scale parameter</td>
<td>$\beta/\zeta$</td>
<td>1.65</td>
<td>Long-run growth rate of the French economy</td>
</tr>
<tr>
<td>Regulatory implicit tax</td>
<td>$\tau$</td>
<td>0.025 (0.011,0.049)</td>
<td>Fall in slope of innovation-firm size relationship for big firms (after threshold) compared to small firms (given $\eta$)</td>
</tr>
<tr>
<td>Output adjusted wage</td>
<td>$\omega$</td>
<td>0.26 (0.22,0.30)</td>
<td>Firm size distribution (slope of power law steeper in log-log space when $\omega$ larger )</td>
</tr>
</tbody>
</table>
Aggregate Innovation falls by about 5.4% (estimated tax of 2.5%)
Aggregate Innovation falls by about 5.4% (estimated tax of 2.5%)

Note: Model uses parameters as estimated in Table 3. In sensitivity tests range of innovation losses are between 1.3% and 9.8%.
Decomposing aggregate effects (shift share relative to unregulated economy)

\[
Z(\tau) - Z(0) = \sum_{n>0} (Z(n,\tau) - Z(n,0)) \mu(n,0) \\
+ \sum_{n>0} (\mu(n,\tau) - \mu(n,0)) Z(n,0) \\
+ \sum_{n>0} (\mu(n,\tau) - \mu(n,0))(Z(n,\tau) - Z(n,0)) \\
+ \varepsilon(\tau) - \varepsilon(0),
\]

Lower firm innovation (evaluated at unregulated firm size distribution)
Shift in firm size (evaluated at unregulated firm innovation)
Interaction
Entry

80% of the aggregate effect is the first row: lower innovation by incumbent given firm size distribution
Sensitivity of aggregate innovation losses to changes in assumptions over parameters

Table 4: Sensitivity analysis

<table>
<thead>
<tr>
<th>Robustness</th>
<th>Loss in total innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>5.42%</td>
</tr>
<tr>
<td>$\gamma = 1.05$</td>
<td>5.33%</td>
</tr>
<tr>
<td>$\gamma = 1.50$</td>
<td>5.45%</td>
</tr>
<tr>
<td>$\eta = 2$</td>
<td>2.76%</td>
</tr>
<tr>
<td>$\eta = 1.3$</td>
<td>8.80%</td>
</tr>
<tr>
<td>$\omega = 0.22$</td>
<td>5.35%</td>
</tr>
<tr>
<td>$\omega = 0.29$</td>
<td>5.45%</td>
</tr>
<tr>
<td>$\beta/\zeta = 1.40$</td>
<td>5.42%</td>
</tr>
<tr>
<td>$\beta/\zeta = 1.90$</td>
<td>5.42%</td>
</tr>
<tr>
<td>$\tau$</td>
<td></td>
</tr>
<tr>
<td>Percentile 75th</td>
<td>9.75%</td>
</tr>
<tr>
<td>Percentile 25th</td>
<td>1.40%</td>
</tr>
</tbody>
</table>

Notes: baseline uses parameter values: ($\eta = 1.5$, $\gamma = 1.3$, $\tau = 0.025$, $\beta/\zeta = 1.65$ and $\omega = 0.25$), see Table 3. In the robustness where $\gamma$, $\eta$, $\omega$ or $\beta/\zeta$ are changed, we keep $\tau$ as in the baseline. The last two lines report the 25th and 75th percentile for the loss of innovation in a sample computed from 100,000 independent draws of $\tau$ from two normal distributions. The corresponding value of $\tau$ and $\beta/\zeta$ are computed as an average for each percentile. Loss in welfare is given in consumption equivalent and does not include initial quality (see section 4.3).  

Note: Table C2 shows variety of empirically estimating $\tau$ (0.011 to 0.049) generating innovation loss of between 2.2% and 11.4%)
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, 2020; 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 \( \tau \))

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

Lower growth under regulation  \quad R&D saving  \quad Loss of static efficiency

• Net effect is 2.2% consumption equivalent loss

• First term dominates: 5.4% slower growth

• This is lower bound, as we know static effect (3rd term) is negative, but hard to calculate without more assumptions (e.g. 1.3-3.4% in Garicano et al, 2016).
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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 $\alpha = \ldots$. 
Fig 9: 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 (grey line) and the share of firms with at least one priority patent among the bottom 90% most cited in the year (black 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 (154,582 firms and 1,439,396 observations).
Tab 3: Weaker effect of demand shocks below threshold only exist for incremental innovation

<table>
<thead>
<tr>
<th>Quality</th>
<th>Top 10%</th>
<th>Top 15%</th>
<th>Top 25%</th>
<th>Bottom 75%</th>
<th>Bottom 85%</th>
<th>Bottom 90%</th>
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<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
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<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
</tr>
<tr>
<td>$Shock_{t-2} \times L_{t-2}^*$</td>
<td>-0.825</td>
<td>0.953</td>
<td>-1.661</td>
<td>-15.475**</td>
<td>-12.982*</td>
<td>-16.117**</td>
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<tr>
<td>$L_{t-2}^*$</td>
<td>-0.051</td>
<td>-0.026</td>
<td>0.001</td>
<td>0.109</td>
<td>0.147</td>
<td>0.119</td>
</tr>
<tr>
<td></td>
<td>(0.047)</td>
<td>(0.074)</td>
<td>(0.088)</td>
<td>(0.135)</td>
<td>(0.138)</td>
<td>(0.144)</td>
</tr>
<tr>
<td>$Shock_{t-2}$</td>
<td>-1.857</td>
<td>-3.710</td>
<td>-12.263***</td>
<td>-1.920</td>
<td>-7.715</td>
<td>-8.314*</td>
</tr>
<tr>
<td></td>
<td>(2.059)</td>
<td>(3.222)</td>
<td>(4.614)</td>
<td>(5.156)</td>
<td>(4.929)</td>
<td>(4.588)</td>
</tr>
<tr>
<td>$log(L)_{t-2}$</td>
<td>0.015</td>
<td>-0.004</td>
<td>-0.045*</td>
<td>-0.037*</td>
<td>0.002</td>
<td>-0.056**</td>
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<tr>
<td></td>
<td>(0.019)</td>
<td>(0.025)</td>
<td>(0.026)</td>
<td>(0.020)</td>
<td>(0.016)</td>
<td>(0.026)</td>
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<tr>
<td>$Shock_{t-2} \times log(L)_{t-2}$</td>
<td>0.624</td>
<td>1.198</td>
<td>3.825**</td>
<td>3.156*</td>
<td>1.553</td>
<td>3.414**</td>
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<td></td>
<td>(0.681)</td>
<td>(1.111)</td>
<td>(1.474)</td>
<td>(1.658)</td>
<td>(1.708)</td>
<td>(1.515)</td>
</tr>
</tbody>
</table>

**Fixed Effects**

- Sector: ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
- Year: ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
- Number Obs.: 186,337 186,337 186,337 186,337 186,337 186,337

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 3-digit NACE sector and a year fixed effects. Estimation period: 1997-2007. Standard errors are clustered at the 3-digit NACE sector level. ***, ** and * indicate p-value below 0.01, 0.05 and 0.1 respectively.
Fig 10: Implied Marginal effect of demand shocks on innovation by firm size

Note: These are based on the estimates in columns (1) and (6) of Table 3
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

<table>
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<tr>
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<th>(3)</th>
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<td></td>
<td>(5.806)</td>
<td>(5.880)</td>
<td>(5.874)</td>
<td>(6.379)</td>
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<td>(5.897)</td>
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<td>$L_{t-2}^*$</td>
<td>0.045</td>
<td>0.066</td>
<td>0.066</td>
<td>0.118</td>
<td>0.086</td>
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<tr>
<td></td>
<td>(0.138)</td>
<td>(0.147)</td>
<td>(0.146)</td>
<td>(0.229)</td>
<td>(0.086)</td>
<td>(0.150)</td>
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<tr>
<td>$log(L)_{t-2}$</td>
<td>-0.036</td>
<td>0.012</td>
<td>-0.040</td>
<td>0.008</td>
<td>-0.199**</td>
<td>-0.028</td>
<td>-0.065**</td>
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<td>(0.027)</td>
<td>(0.104)</td>
<td>(0.031)</td>
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<td>(0.083)</td>
<td>(0.017)</td>
<td>(0.030)</td>
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<td>$Shock_{t-2} \times log(L)_{t-2}$</td>
<td>3.270**</td>
<td>-10.853</td>
<td>3.898***</td>
<td>-9.281</td>
<td>3.857**</td>
<td>2.552***</td>
<td>4.009***</td>
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<td>(1.374)</td>
<td>(7.524)</td>
<td>(1.392)</td>
<td>(7.490)</td>
<td>(1.552)</td>
<td>(0.913)</td>
<td>(1.431)</td>
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<td>$log(L)_{t-2}^2$</td>
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<td>(0.019)</td>
<td></td>
<td>(0.151)</td>
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<tr>
<td>$Shock_{t-2} \times log(L)_{t-2}^2$</td>
<td>2.182*</td>
<td></td>
<td></td>
<td>2.031</td>
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<td></td>
<td>(1.291)</td>
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<td>(1.287)</td>
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<tr>
<td>$\Delta log(L)_{t-2}$</td>
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<td></td>
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<td></td>
<td>0.156</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.151)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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

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4. Results & Aggregate Implications

5. Extensions
   • Incremental & radical innovation
   • Empirical robustness
   • Generalizing theory: R&D as scientists; infinitely lived agents
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 and R&D.
- No longer a closed form: Model must be solved numerically as Main results go through, but regulation now also depresses equilibrium wages.
Fig C4: Innovation and Firm size in the R&D as scientist model
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
  – Evidence for this in static and dynamic analysis

• Aggregate effects look important: around 5.4% fall in innovation (2.2% 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!
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

• Therefore a firm cannot extend its size by more than 1 product line in a generation

• In general model (Appendix C) we allow owners to live multiple periods (so allow infinitely lived firms) and same intuitions go through
<table>
<thead>
<tr>
<th>Observations</th>
<th>(1)</th>
<th>(2)</th>
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<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.5%</td>
<td>4.9%</td>
<td>1.1%</td>
<td>1.9%</td>
<td>1.4%</td>
<td>3.0%</td>
<td>3.6%</td>
<td>3.2%</td>
</tr>
<tr>
<td>$\tau$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Innovation loss</td>
<td>0.950</td>
<td>0.886</td>
<td>0.978</td>
<td>0.959</td>
<td>0.971</td>
<td>0.934</td>
<td>0.920</td>
<td>0.929</td>
</tr>
<tr>
<td>Welfare loss</td>
<td>0.980</td>
<td>0.918</td>
<td>0.995</td>
<td>0.988</td>
<td>0.993</td>
<td>0.971</td>
<td>0.958</td>
<td>0.967</td>
</tr>
</tbody>
</table>

**Notes:** This Table presents alternative OLS estimates of parameter $\tau$ based on the innovation-employment relationship of equation (3). $\tau$ 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 3 which extend this to 150). Left-hand side variable is the number of patents computed as a five year average around $t$ (columns 1, 2, 3, 6, 7 and 8), in years $t+1$, $t+2$ and $t+3$ (column 4) and in year $t+1$ (column 5). Observations are either binned at the employment level (one observation per level of employment) in columns 1 to 5 or at the firm level and pooled together for other columns. Column 6 includes a 3-digit sector fixed effect, column 7 includes adds a year fixed effect (on top of the sector) and column 8 includes a interacted sector-year fixed effect. Each estimation includes dummies for each employment level between 46 and 49.
Share of innovative firms at different firm employment levels

Flattening of the innovation-size Relationship after the threshold

**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 C2: Alternative estimation of $\tau$

<table>
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<tr>
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<tr>
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<tr>
<td>Employment binned</td>
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<td></td>
</tr>
<tr>
<td>$\tau$</td>
<td>2.5%</td>
<td>4.9%</td>
<td>1.1%</td>
<td>1.9%</td>
<td>1.4%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Firm level</td>
<td></td>
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<td></td>
<td></td>
<td>3.0%</td>
<td>3.6%</td>
<td>3.2%</td>
</tr>
<tr>
<td>Total Innovation loss</td>
<td>0.950</td>
<td>0.886</td>
<td>0.978</td>
<td>0.959</td>
<td>0.971</td>
<td>0.934</td>
<td>0.920</td>
<td>0.929</td>
</tr>
<tr>
<td>Welfare loss</td>
<td>0.980</td>
<td>0.918</td>
<td>0.995</td>
<td>0.988</td>
<td>0.993</td>
<td>0.971</td>
<td>0.958</td>
<td>0.967</td>
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</table>

**Notes:** This Table presents alternative OLS estimates of parameter $\tau$ based on the innovation-employment relationship of equation (3). $\tau$ 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 3 which extend this to 150). Left-hand side variable is the number of patents computed as a five year average around $t$ (columns 1, 2, 3, 6, 7 and 8), in years $t+1$, $t+2$ and $t+3$ (column 4) and in year $t+1$ (column 5). Observations are either binned at the employment level (one observation per level of employment) in columns 1 to 5 or at the firm level and pooled together for other columns. Column 6 includes a 3-digit sector fixed effect, column 7 includes adds a year fixed effect (on top of the sector) and column 8 includes a interacted sector-year fixed effect. 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 D3: Response to the Demand shock of patents of different quality

Notes: 95% confidence intervals around the estimated coefficient $\delta$ in equation (5). 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.
Infinitely Lived Agents

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

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

- Let \( \rho = (1 - \beta)/\beta \) and \( W(n) = \beta V(n)/y \)
- Bellman Equation

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

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