Innovation, Reallocation and Growth[1]

Daron Acemoglu
MIT

NYU, April 11, 2013.

[1] Joint with Ufuk Akcigit (U. Penn), Nick Bloom (Stanford) and Bill Kerr (Harvard)

Motivation (I)

- Recent economic recession has reopened the debate on industrial policy.
- In October 2008, the US government bailed out GM and Chrysler. (Estimated cost, $82 Billion)
- Similar bailouts in Europe: Estimated cost €1.18 trillion in 2010, 9.6% of EU GDP.
- Many think that this was a success from a short-term perspective, because these interventions
  - protected employment, and
  - encouraged incumbents to undertake greater investments,

Motivation (II)

- But what was the cost of the bailout?
  - More generally, what are the costs of "industrial policy"?
- Bailouts or support for incumbents could increase growth if there is insufficient entry or if they support incumbent R&D.
  - In fact, this is recently been articulated as an argument for industrial policy.
- They may reduce growth by
  - preventing the entry of more efficient firms and
  - slowing down the reallocation process.
- Reallocation potentially important, estimated sometimes to be responsible for up to 70-80% of US productivity growth.

Question

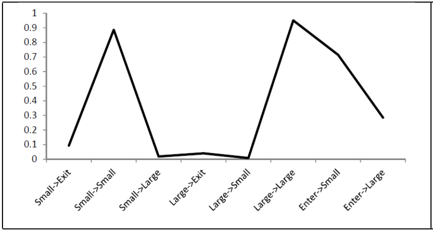
- General question: What are the effects of industrial policies on aggregate innovation and productivity growth?
- Specific channel: Firm innovation, dynamics, selection and reallocation.

Motivation & Question (III)

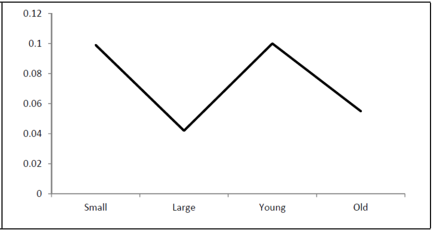
- But we need a framework to answer these questions.
- Such a framework should accommodate:
    1. different types of policies (subsidies to operation vs R&D),
    2. general equilibrium structure (for the reallocation aspect),
    3. exit for less productive firms/products (so that the role of subsidies that directly or indirectly prevent exit can be studied), and
    4. meaningful heterogeneity at the firm level (important for matching the data at a minimal level and also for selection effects).

Why Heterogeneity Matters

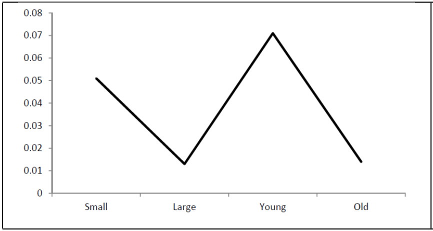
1A: Transition Rates



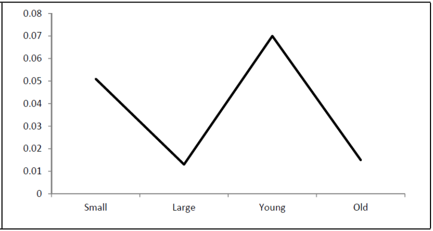
1B: R&D Intensity



1C: Sales Growth



1D: Employment Growth



Features of the Model

- Starting point: Klette and Kortum's (2004) model of micro innovation building up to macro structure.
  - But Klette and Kortum's model incorporates no heterogeneity, no reallocation or no exit.
- Our framework:
  - general equilibrium: fixed supply of skilled labor
  - exit for less productive firms/products: due to fixed cost of operation
  - meaningful heterogeneity at the firm level: firms enter as high or low type in terms of innovativeness and firm type evolves over time $\Longrightarrow$ *selection*

Summary of Results

- The model provides a fairly good fit to micro and macro data.
- Using the estimate of parameter values, industrial policy in the form of subsidies to incumbent R&D or subsidies to the continued operation of incumbents reduces growth—e.g., a subsidy worth 5% of GDP reduces long-run growth from 2.24% to 2.16%.
- This is not because the equilibrium is efficient. In fact, it is highly inefficient.
  - A social planner can increase growth to 3.8% (without manipulating markups).
- A (large) tax on continued operations plus a small subsidy to incumbent R&D can also increase growth to 3.11%.
  - Works by freeing resources to be used in R&D by high-type firms—selection effect.
- Bottom line:optimal policy should go in the opposite direction of industrial policy—to leverage selection and free resources away from inefficient incumbents.

Outline

- Introduction.
- Model.
- Estimation strategy & results.
- Policy experiments.

MODEL

Baseline Model: Preferences

- Simplified model (abstracting from heterogeneity and non-R&D growth).
- Infinite-horizon economy in continuous time.
- Representative household:

$$U = \int_0^\infty \exp(-\rho t) \frac{C(t)^{1-\theta} - 1}{1-\theta} dt.$$

- Inelastic labor supply, no occupational choice:
  - Unskilled for production: measure 1, earns w^u
  - Skilled for R&D: measure L, earns w^s.
- Hence the budget constraint is

$$C(t) + \dot{A}(t) \leq w^u(t) + w^s(t) \cdot L + r(t) \cdot A(t)$$

- Closed economy and no investment, resource constraint:

$$Y(t) = C(t).$$

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$$C \quad + \dot{A} \quad \leq w^u \quad + w^s \quad \cdot L + r \quad \cdot A$$

- Closed economy and no investment, resource constraint:

$$Y \quad = C$$

Final Good Technology

- Unique final good Y :

$$Y = \left(\int_{\mathcal{N}} y_j^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}} .$$

- $\mathcal{N} \subset [0, 1]$ is the set of *active* product lines.
- The measure of $\mathcal{N}$ is less than 1 due to
  1. exogenous destructive shock
  2. obsolescence

Intermediate Good Technology

- Each intermediate good is produced by a **monopolist**:

$$y_{j,f} = q_{j,f} l_{j,f},$$

$q_{j,f}$: worker productivity, $l_{j,f}$: number of workers.

- Marginal cost :

$$MC_{j,f} = \frac{w^u}{q_{j,f}}.$$

- Fixed cost of production, ϕ in terms of skilled labor.
- Total cost

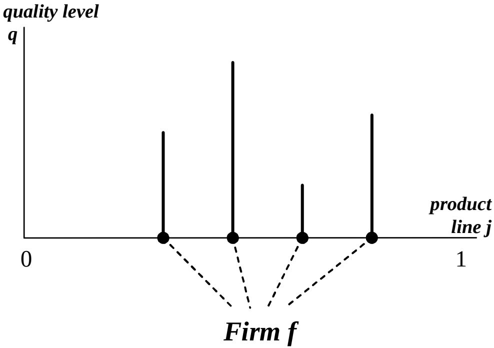
$$TC_{j,f}(y_{j,f}) = w^s \phi + w^u \frac{y_{j,f}}{q_{j,f}}.$$

Definition of a Firm

- A firm is defined as a collection of product qualities

$$\text{Firm } f = \mathcal{Q}_f \equiv \left\{ q_f^1, q_f^2, ..., q_f^n \right\}.$$

$n_f \equiv \left| \mathcal{Q}_f \right|$: is the number of product lines of firm f.



Relative Quality

- Define *aggregate quality* as

$$Q \equiv \left(\int_{\mathcal{N}} q_j^{\varepsilon-1} dj \right)^{\frac{1}{\varepsilon-1}}.$$

- In equilibrium,

$$Y = C = Q,$$

- Define *relative quality*:

$$\hat{q}_j \equiv \frac{q_j}{w^u}.$$

R&D and Innovation

- Innovations follow a "controlled" Poisson Process

$$X_f = n_f^{\gamma} h_f^{1-\gamma}.$$

X_f : flow rate of innovation
n_f : number of product lines.
h_f : number of researchers (here taken to be regular workers allocated to research).

- This can be rewritten as *per product* innovation at the rate

$$x_f \equiv \frac{X_f}{n_f} = \left(\frac{h_f}{n_f}\right)^{1-\gamma}.$$

- Cost of R&D as a function of per product innovation rate x_f:

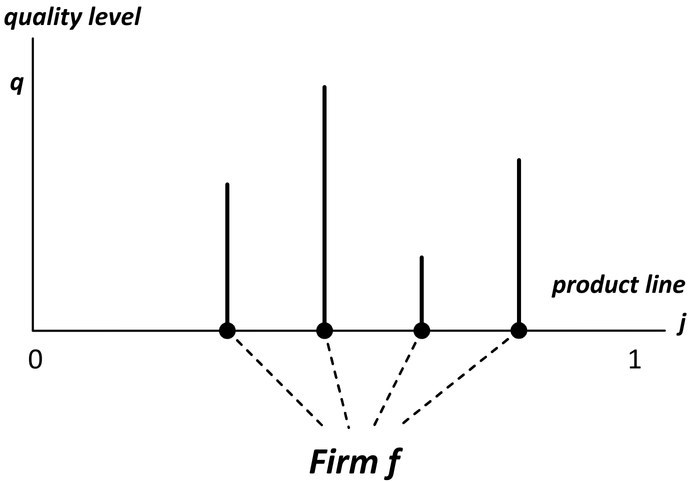
$$w^s G(x_f) \equiv w^s n_f x_f^{\frac{1}{1-\gamma}}.$$

Innovation by Existing Firms

- Innovations are *undirected* across product lines.
- Upon an innovation:
  1. firm f acquires another product line j
  2. if technology in j is active:

$$q(j, t + \Delta t) = (1 + \lambda) q(j, t).$$

  3. if technology in j is not active, i.e., $j \notin \mathcal{N}$, a new technology is drawn from the steady-state distribution of relative quality, $F(\hat{q})$.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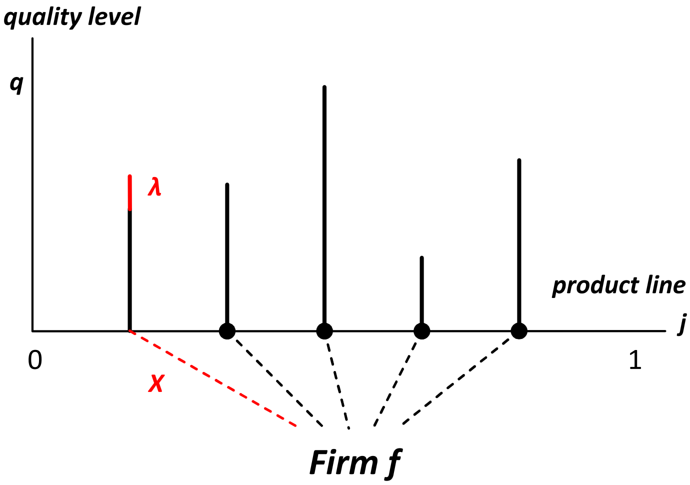
Firm f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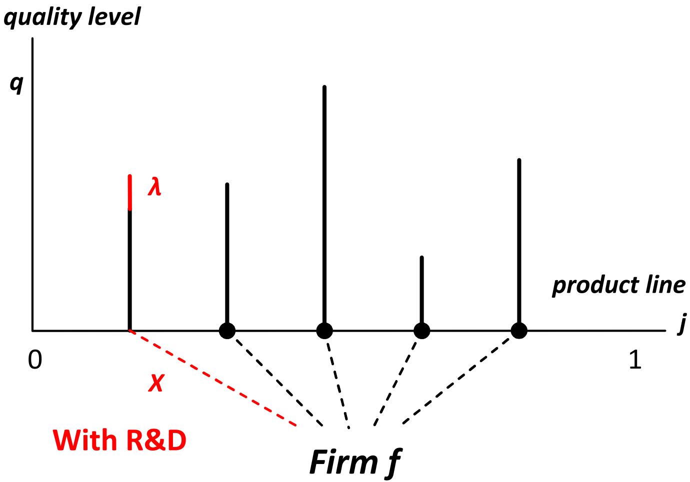
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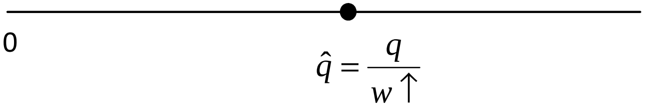
With R&D
Firm f

Entry and Exit

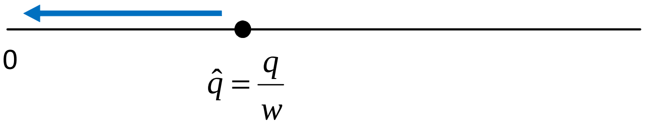
- A set of potential entrants invest in R&D.
- Exit happens in three ways:
  1. **Creative destruction**. Firm f will lose each of its products at the rate $\tau > 0$ which will be determined endogenously in the economy.
  2. **Exogenous destructive shock** at the rate φ.
  3. **Obsolescence**. Relative quality decreases due to the increase in the wage rate, at some point leading to exit.

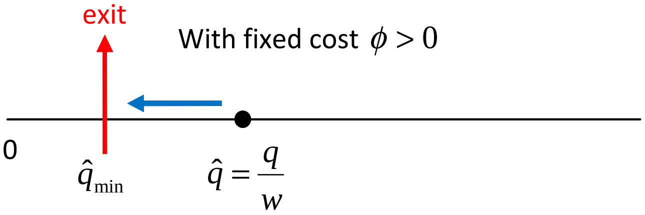

0
$\hat{q} = \frac{q}{w}$

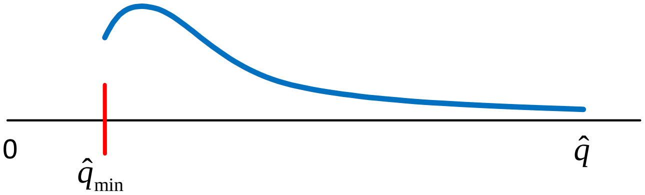

0
$\hat{q} = \frac{q}{w\uparrow}$


0
$\hat{q} = \frac{q}{w\uparrow}$

Without a fixed cost




exit
With fixed cost $\phi > 0$
0
$\hat{q}_{\min}$
$\hat{q} = \frac{q}{w}$


0
$\hat{q}_{\min}$
$\hat{q}$

Static Equilibrium

- Drop the time subscripts.
- Isoelastic demands imply the following monopoly price and quantity

$$p_{j,f}^{*} = \left(\frac{\varepsilon}{\varepsilon - 1}\right)\frac{1}{\hat{q}_j} \text{ and } c_j^{*} = \left(\frac{\varepsilon - 1}{\varepsilon}\hat{q}_j\right)^{\varepsilon} Y$$

- In equilibrium,

$$Y = C = Q$$

and

$$w^u = \frac{\varepsilon - 1}{\varepsilon} Q.$$

- Therefore the gross equilibrium (before fixed costs) profits from a product with relative quality $\hat{q}_j$ are:

$$\pi\left(\hat{q}_{j,f}\right) = \hat{q}_j^{\varepsilon - 1}\left(\frac{(\varepsilon - 1)^{\varepsilon - 1}}{\varepsilon^{\varepsilon}}\right) Y.$$

Dynamic Equilibrium

- Let us also define *normalized values* as

$$\tilde{V} \equiv \frac{V}{Y}, \;\; \tilde{\pi}\left(\hat{q}_{j,f}\right) = \frac{\pi\left(\hat{q}_{j,f}\right)}{Y}, \;\; \tilde{w}^u \equiv \frac{w^u}{Y} \text{ and } \tilde{w}^s \equiv \frac{w^s}{Y}.$$

Dynamic Equilibrium (continued)

$$r^* \tilde{V}\left(\hat{\mathcal{Q}}_f\right) = \left[\begin{array}{c} \sum_{\hat{q}_{j,f} \in \hat{\mathcal{Q}}_f} \left\{ \begin{array}{c} \tilde{\pi}\left(\hat{q}_{jf}\right) - \tilde{w}^s \phi_j \\ + \dot{\tilde{V}} \\ +\tau \left[\tilde{V}\left(\hat{\mathcal{Q}}_f \setminus \left\{\hat{q}_{jf}\right\}\right) - \tilde{V}\left(\hat{\mathcal{Q}}_f\right) \right] \end{array} \right\} + \\ \left|\hat{\mathcal{Q}}_f\right| \max_{x_f} \left\{ \begin{array}{c} -\tilde{w} G\left(x_f\right) \\ +x_f \left[\mathbb{E}_{\hat{q}} \tilde{V}\left(\hat{\mathcal{Q}}_f \cup (1+\lambda)\, \hat{q}_{j',f}\right) - \tilde{V}\left(\hat{\mathcal{Q}}_f\right) \right] \end{array} \right\} \\ +\varphi \left[0 - \tilde{V}\left(\hat{\mathcal{Q}}_f\right) \right] \end{array} \right.$$

τ: creative destruction rate in the economy.

Dynamic Equilibrium (continued)

$$r^* \tilde{V}\left(\hat{\mathcal{Q}}_f\right) = \left[\begin{array}{c} \sum_{\hat{q}_{j,f} \in \hat{\mathcal{Q}}_f} \left\{ \begin{array}{c} \tilde{\pi}\left(\hat{q}_{jf}\right) - \tilde{w}^s \phi_j \\ + \frac{\partial \tilde{V}}{\partial \hat{q}_{jf}} \frac{\partial \hat{q}_{jf}}{\partial w^u(t)} \frac{\partial w^u(t)}{\partial t} \\ + \tau \left[\tilde{V}\left(\hat{\mathcal{Q}}_f \setminus \left\{\hat{q}_{jf}\right\}\right) - \tilde{V}\left(\hat{\mathcal{Q}}_f\right) \right] \end{array} \right\} + \\ \left|\hat{\mathcal{Q}}_f\right| \max_{x_f} \left\{ \begin{array}{c} -\tilde{w} G\left(x_f\right) \\ + x_f \left[\mathbb{E}_{\hat{q}} \tilde{V}\left(\hat{\mathcal{Q}}_f \cup (1+\lambda)\hat{q}_{j',f}\right) - \tilde{V}\left(\hat{\mathcal{Q}}_f\right) \right] \end{array} \right\} \\ + \varphi \left[0 - \tilde{V}\left(\hat{\mathcal{Q}}_f\right) \right] \end{array}\right]$$

τ: creative destruction rate in the economy.

Franchise and R&D Option Values

Lemma *The normalized value can be written as the sum of franchise values:*

$$\tilde{V}\left(\hat{\mathcal{Q}}_f\right) = \sum_{\hat{q}\in\hat{\mathcal{Q}}_f} \Upsilon\left(\hat{q}\right),$$

where the franchise value of a product of relative quality $\hat{q}$ is the solution to the differential equation (iff $\hat{q} \geq \hat{q}_{\min}$):

$$r\Upsilon\left(\hat{q}\right) - \frac{\partial \Upsilon\left(\hat{q}\right)}{\partial \hat{q}} \frac{\partial \hat{q}}{\partial w^u\left(t\right)} \frac{\partial w^u\left(t\right)}{\partial t} = \tilde{\pi}\left(\hat{q}\right) - \tilde{w}^u \phi + \Omega - \left(\tau + \varphi\right)\Upsilon\left(\hat{q}\right),$$

where Ω is the R&D option value of holding a product line,

$$\Omega \equiv \max_{x_f \geq 0}\left\{-\tilde{w}^s G\left(x_f\right) + x_f\left(\mathbb{E}_{\hat{q}}\tilde{V}\left(\hat{\mathcal{Q}}_f \cup \left(1+\lambda\right)\hat{q}_{j'f}\right) - \tilde{V}\left(\hat{\mathcal{Q}}_f\right)\right)\right\},$$

Moreover, exit follows a cut-off rule: $\hat{q}_{\min} \equiv \pi^{-1}\left(\tilde{w}^s\phi - \Omega\right).$

Equilibrium Value Functions and R&D

Proposition

Equilibrium normalized value functions are:

$$\Upsilon(\hat{q}) = \frac{\tilde{\pi}(\hat{q})}{r+\tau+\varphi+g(\varepsilon-1)}\left[1-\left(\frac{\hat{q}_{\min}}{\hat{q}}\right)^{\frac{r+\tau+\varphi+g(\varepsilon-1)}{g}}\right] + \frac{\Omega-\tilde{w}^{s}\phi}{r+\tau+\varphi}\left[1-\left(\frac{\hat{q}_{\min}}{\hat{q}}\right)^{\frac{r+\tau+\varphi}{g}}\right],$$

and equilibrium R&D is

$$x^{*}(\hat{q}) = x^{*} = \left[\frac{(1-\gamma)\,\mathbb{E}_{\hat{q}}\Upsilon(\hat{q})}{\tilde{w}^{s}}\right]^{\frac{1-\gamma}{\gamma}}.$$

Entry

- Entry by outsiders can now be determined by the free entry condition:

$$\max_{x^{entry}\geq 0}\left\{-w^s\phi + x^{entry}\mathbb{E}V^{entry}\left(\hat{q},\theta\right) - w^s G\left(x^{entry},\theta^E\right)\right\} = 0$$

  where $G\left(x^{entry},\theta^E\right)$, as specified above, gives a number of skilled workers necessary for a firm to achieve an innovation rate of x^{entry} (with productivity parameter θ^E).

- $X^{entry} \equiv mx^{entry}$ is the total entry rate where
  - m is the equilibrium measure of entrants, and
  - x^{entry} innvation rate per entrant.

Labor Market Clearing

- Unskilled labor market clearing:

$$1 = \int_{\mathcal{N}(t)} l_j \left(w^u\right) dj.$$

- Skilled labor market clearing

$$L^s = \int_{\mathcal{N}(t)} \left[\phi + h\left(w^s\right)\right] dj + m \left[\phi + G\left(x^{entry}, \theta^E\right)\right].$$

Transition Equations

- Finally, we need to keep track of the distribution of relative quality $\longrightarrow$ stationary equilibrium distribution of relative quality F.
- This can be done by writing transition equations describing the density of relative quality.

FULL MODEL

Preferences and Technology in the General Model

- Same preferences.
- Introduce managerial quality affecting the rate of innovation of each firm.
- Some firms start as more innovative than others, over time some of them lose their innovativeness.
  - Young firms are potentially more innovative but also have a higher rate of failure.
- Introduce non-R&D growth (so as not to potentially exaggerate the role of R&D and capture potential advantages of incumbents).

R&D and Innovation

- Innovations follow a controlled Poisson Process.
- Flow rate of innovation for leader and follower given by

$$X_f = (n_f \theta_f)^\gamma h_f^{1-\gamma}.$$

n_f : number of product lines.
θ_f : firm type (management quality).
h_f : number of researchers.

Innovation Realizations

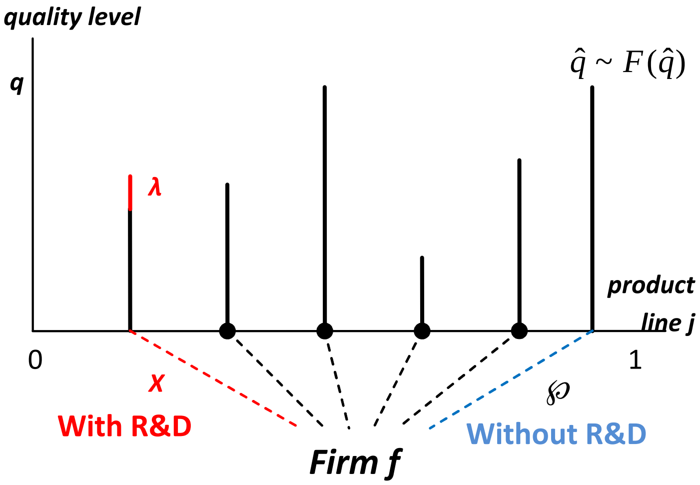
With R&D

- Innovations are *undirected* within the industry.
- After a successful innovation, innovation is realized in a random product line j. Then:
  1. firm f acquires product line j
  2. technology in line j improves

$$q(j, t + \Delta t) = (1 + \lambda) q(j, t).$$

Without R&D

- Firms receive a product line for free at the rate ϱ .


quality level
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$\hat{q} \sim F(\hat{q})$
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product line j
0
1
X
℘
With R&D
Without R&D
Firm f

Definition of a Firm

- A firm is again defined as a technology pair and a management quality pair

$$\text{Firm } f \equiv \left(\mathcal{Q}_f, \theta_f\right),$$

  where

$$\mathcal{Q}_f \equiv \left\{q_f^1, q_f^2, ..., q_f^n\right\}.$$

- $n_f \equiv \left|\mathcal{Q}_f\right|$: is the number of product lines owned by firm f.

Entry and Exit

- There is a measure of potential entrants.
- Successful innovators enter the market.
- At the time of initial entry, each firm draws a management quality θ :

$$\begin{aligned} \Pr\left(\theta = \theta^H\right) &= \alpha \\ \Pr\left(\theta = \theta^L\right) &= 1 - \alpha, \end{aligned}$$

where $\alpha \in (0, 1)$ and $\theta^H > \theta^L > 0$.

- Exit happens in three ways as in the baseline model.

Maturity Shock

- Over time, high-type firms become low-type at the rate $\nu > 0$:

$$\theta^H \longrightarrow \theta^L.$$

- Convenient to capture the possibility of once-innovative firms now being inefficient (and the use of skilled labor).

Equilibrium

- Equilibrium definition and characterization similar to before (with more involved value functions and stationary transition equations).

DATA AND ESTIMATION

Data: LBD, Census of Manufacturing and NSF R&D Data

- Sample from combined databases from 1987 to 1997.
- Longitudinal Business Database (LBD)
  - Annual business registry of the US from 1976 onwards.
  - Universe of establishments, so entry/exit can be modeled.
- Census of Manufacturers (CM)
  - Detailed data on inputs and outputs every five years.
- NSF R&D Survey.
  - Firm-level survey of R&D expenditure, scientists, etc.
  - Surveys with certainty firms conducting $1m or more of R&D.
- USPTO patent data matched to CM.
- Focus on "continuously innovative firms":
  - I.e., either R&D expenditures or patenting in the five-year window surrounding observation conditional on existence.

Data Features and Estimation

- 17,055 observations from 9835 firms.
- Accounts for 98% of industrial R&D.
- Relative to the universal CM, our sample contains over 40% of employment and 65% of sales.
- "Important" small firms also included:
  - of the new entrants or very small firms that later grew to have more than 10,000 employees or more than $1 billion of sales in 1997, we capture, respectively, 94% at 80%.
- We use Simulated Method of Moments on this dataset to estimate the paremeters the parameters of the model.

Creating Moments from the Data

- We target 21 moments to estimate 12 parameters.
- Some of the moments are:
    - Firm entry/exit into/from the economy by age and size.
    - Firm size distribution.
    - Firm growth by age and size.
    - R&D intensity (R&D/Sales) by age and size.
    - Share of entrant firms.

RESULTS

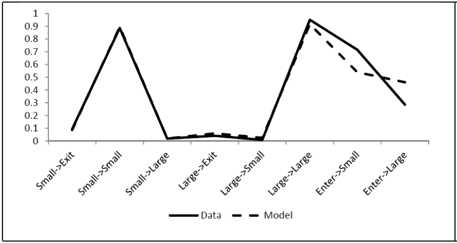
Table 1. Parameter Estimates

#	Parameter	Description	Value
1.	ε	CES	1.701
2.	ϕ	Fixed cost of operation	0.032
3.	L^S	Measure of high-skilled workers	0.078
4.	θ^H	Innovative capacity of high-type firms	0.216
5.	θ^L	Innovative capacity of low-type firms	0.070
6.	θ^E	Innovative capacity of entrants	0.202
7.	α	Probability of being high-type entrant	0.428
8.	ν	Transition rate from high-type to low-type	0.095
9.	λ	Innovation step size	0.148
10.	γ	Innovation elasticity wrt knowledge stock	0.637
11.	φ	Exogenous destruction rate	0.016
12.	ϱ	Non-R&D innovation arrival rate	0.012

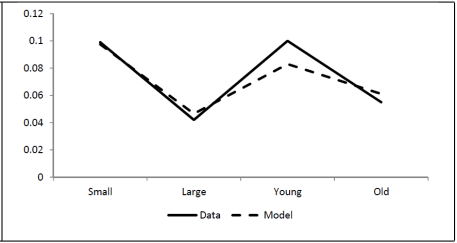
Table 2. Moment Matching

#	Moments	model	data		#	Moments	model	data
1.	Firm Exit (small)	0.086	0.093		12.	Sales Gr. (small)	0.115	0.051
2.	Firm Exit (large)	0.060	0.041		13.	Sales Gr. (large)	-0.004	0.013
3.	Firm Exit (young)	0.078	0.102		14.	Sales Gr. (young)	0.070	0.071
4.	Firm Exit (old)	0.068	0.050		15.	Sales Gr. (old)	0.030	0.014
5.	Trans. large-small	0.024	0.008		16.	R&D/Sales (small)	0.097	0.099
6.	Trans. small-large	0.019	0.019		17.	R&D/Sales (large)	0.047	0.042
7.	Prob. small	0.539	0.715		18.	R&D/Sales (young)	0.083	0.100
8.	Emp. Gr. (small)	0.063	0.051		19.	R&D/Sales (old)	0.061	0.055
9.	Emp. Gr. (large)	-0.007	0.013		20.	5-year Ent. Share	0.363	0.393
10.	Emp. Gr. (young)	0.040	0.070		21.	Aggregate growth	0.022	0.022
11.	Emp. Gr. (old)	0.010	0.015					

2A: Transition Rates



2B: R&D Intensity



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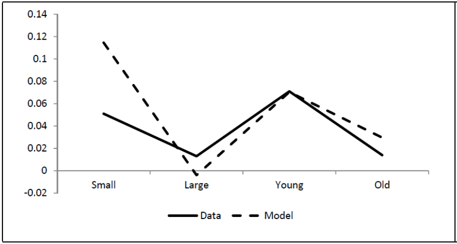
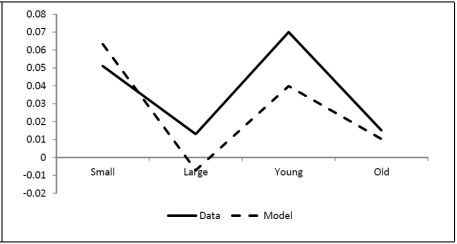


2D: Employment Growth



Non-Targeted Moments

Table 3: Non-targeted Moments

Moments	Model	Data
Corr(exit prob, R&D intensity)	0.04	0.05
Exit prob of low-R&D-intensive firms	0.36	0.32
Exit prob of high-R&D-intensive firms	0.37	0.34
Corr(R&D growth, emp growth)	0.48	0.19
Share firm growth due to R&D	0.77	0.73
Ratio of top 7.2% to bottom 92.8% income	13.4	9.3

Comparison to Micro Estimates

- Estimates of the elasticity of patents (innovation) to R&D expenditures (e.g., Griliches, 1990):
  - [0.3, 0.6]
  - This corresponds to $1-\gamma$, so a range of $[0.4, 0.7]$ for γ.
  - Our estimate is in the middle of this range.
- Use IV estimates from R&D tax credits.
  - US spending about $2 billion with large cross-state over-time variation.
  - Literature estimates:

$$\log(R\&D_{i,t}) = \alpha_i + \beta_t + \gamma \log(R\&D\_Cost\_of\_Capital_{i,t})$$

  - Bloom, Griffith and Van Reenen (2002) find -1.088 (0.024) on a cross-country panel. Similar estimates from Hall (1993), Baily and Lawrence (1995) and Mumuneas and Nadiri (1996).
  - In the model, $\ln R\&D = \frac{\gamma-1}{\gamma} \ln\left(c_{R\&D}\right)$ +constant.
  - So approximately $\gamma \approx 0.5$, close to our estimate of $\gamma = 0.637$.

POLICY EXPERIMENTS

Baseline Results

Table 4. Baseline Model

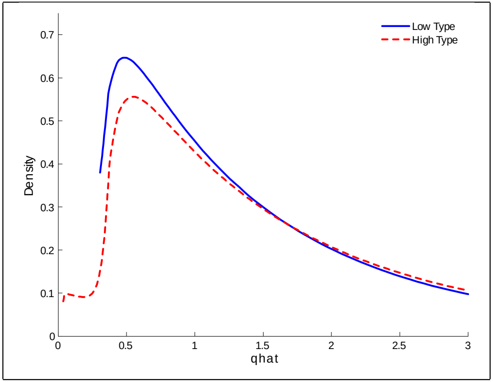
x^{entry}	x^l	x^h	m	Φ^l	Φ^h	$\hat{q}_{l,\min}$	$\hat{q}_{h,\min}$	g	Wel
8.46	2.80	9.58	73.6	71.16	24.53	13.90	0.00	2.24	100

Note: All numbers except wage ratio and welfare are in percentage terms.

- g : growth rate
- x^{out} : entry rate
- x^{low} : low-type innv rate
- x^{high} : high-type innv rate
- Φ^{low} : fraction of low p. lines
- Φ^{high} : fraction of high p. lines
- $\hat{q}_{l,\min}$: low-type cutoff quality
- $\hat{q}_{h,\min}$: high-type cutoff quality
- wel : welfare in cons equiv.

Relative Quality Distribution

FIGURE 3



- Explains why very little obsolescence of high-type products.

Policy Analysis: Subsidy to Incumbent R&D

TABLE 4. BASELINE MODEL

x^{entry}	x^l	x^h	m	Φ^l	Φ^h	$\hat{q}_{l,\min}$	$\hat{q}_{h,\min}$	g	Wel
8.46	2.80	9.58	73.6	71.16	24.53	13.90	0.00	2.24	100

- Use 1% and 5% of GDP, resp., to subsidize incumbents R&D:

TABLE 5A. INCUMBENT R&D SUBSIDY ($s_i = 15\%$)

x^{entry}	x^l	x^h	m	Φ^l	Φ^h	$\hat{q}_{l,\min}$	$\hat{q}_{h,\min}$	g	Wel
8.46	3.05	10.56	68.1	70.74	24.96	13.40	0.00	2.23	99.86

TABLE 5B. INCUMBENT R&D SUBSIDY ($s_i = 39\%$)

x^{entry}	x^l	x^h	m	Φ^l	Φ^h	$\hat{q}_{l,\min}$	$\hat{q}_{h,\min}$	g	Wel
8.46	3.61	13.04	49.8	69.58	25.97	13.15	0.00	2.16	98.48

Policy Analysis: Subsidy to the Operation of Incumbents

Table 4. Baseline Model

x^{entry}	x^l	x^h	m	Φ^l	Φ^h	$\hat{q}_{l,\min}$	$\hat{q}_{h,\min}$	g	Wel
8.46	2.80	9.58	73.6	71.16	24.53	13.90	0.00	2.24	100

- Use 1% of GDP to subsidize operation costs of incumbents:

Table 6. Operation Subsidy ($s_o = 6\%$)

x^{entry}	x^l	x^h	m	Φ^l	Φ^h	$\hat{q}_{l,\min}$	$\hat{q}_{h,\min}$	g	Wel
8.46	2.80	9.59	73.7	71.30	24.52	11.74	0.00	2.22	99.82

- Now an important negative selection effect.

Policy Analysis: Entry Subsidy and Selection

TABLE 4. BASELINE MODEL

x^{entry}	x^l	x^h	m	Φ^l	Φ^h	$\hat{q}_{l,\min}$	$\hat{q}_{h,\min}$	g	Wel
8.46	2.80	9.58	73.6	71.16	24.53	13.90	0.00	2.24	100

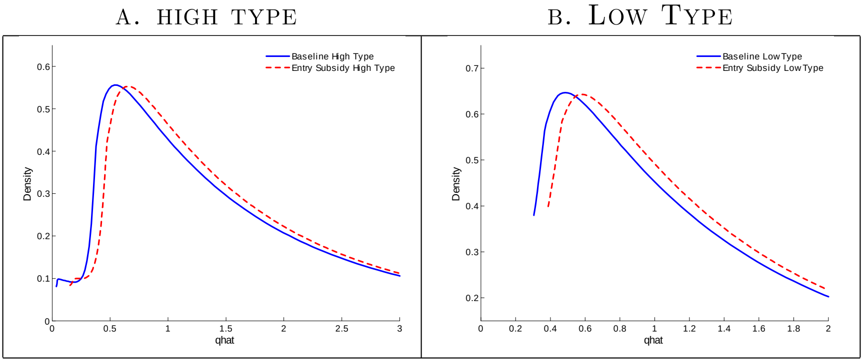
- Use 1% of GDP to subsidize entry:

TABLE 7. ENTRY SUBSIDY ($s_e = 5\%$)

x^{entry}	x^l	x^h	m	Φ^l	Φ^h	$\hat{q}_{l,\min}$	$\hat{q}_{h,\min}$	g	Wel
8.46	2.73	9.30	75.3	71.16	24.41	15.91	0.00	2.26	100.15

Understanding the Selection Effect

Figure 4. Policy effect on Productivity Distributions



Social Planner's Allocation

TABLE 4. BASELINE MODEL

x^{entry}	x^l	x^h	m	Φ^l	Φ^h	$\hat{q}_{l,\min}$	$\hat{q}_{h,\min}$	g	Wel
8.46	2.80	9.58	73.6	71.16	24.53	13.90	0.00	2.24	100

- What would the social planner do (taking equilibrium markups as given)?

TABLE 8. SOCIAL PLANNER

x^{entry}	x^l	x^h	m	Φ^l	Φ^h	$\hat{q}_{l,\min}$	$\hat{q}_{h,\min}$	g	Wel
8.46	2.55	10.47	80.9	54.06	27.76	118.6	1.02	3.80	106.5

Optimal Policy (I)

TABLE 4. BASELINE MODEL

x^{entry}	x^l	x^h	m	Φ^l	Φ^h	$\hat{q}_{l,\min}$	$\hat{q}_{h,\min}$	g	Wel
8.46	2.80	9.58	73.6	71.16	24.53	13.90	0.00	2.24	100

- Optimal mix of incumbent R&D subsidy, operation subsidy and entry subsidy:

TABLE 9. OPTIMAL POLICY ANALYSIS AND WELFARE

INCUMBENT & ENTRY POLICIES ($s_i = 17\%, s_o = -246\%, s_e = 6\%$)									
x^{entry}	x^l	x^h	m	Φ^l	Φ^h	$\hat{q}_{l,\min}$	$\hat{q}_{h,\min}$	g	Wel
8.46	3.04	10.21	75.5	62.19	25.53	96.28	55.88	3.12	104.6

Optimal Policy (II)

Table 4. Baseline Model

x^{entry}	x^l	x^h	m	Φ^l	Φ^h	$\hat{q}_{l,\min}$	$\hat{q}_{h,\min}$	g	Wel
8.46	2.80	9.58	73.6	71.16	24.53	13.90	0.00	2.24	100

- Optimal mix of incumbent R&D subsidy and operation subsidy:

Table 9. Optimal Policy Analysis and Welfare

Incumbent Policies ($s_i = 12\%, s_o = -264\%$)									
x^{entry}	x^l	x^h	m	Φ^l	Φ^h	$\hat{q}_{l,\min}$	$\hat{q}_{h,\min}$	g	Wel
8.46	3.04	10.21	75.3	62.31	25.53	91.38	54.85	3.11	104.6

Summing up

- Industrial policy directed at incumbents has negative effects on innovation and productivity growth—though small.
- Subsidy to entrants has small positive effects.
- But not because R&D incentives are right in the laissez-faire equilibrium.
- The social planner can greatly improve over the equilibrium.
- Similar gains can also be achieved by using taxes on the continued operation of incumbents (plus small R&D subsidies).
    - This is useful for encouraging the exit of inefficient incumbents who are trapping skilled labor that can be more productively used by entrants and high-type incumbents.

Robustness

- These results are qualitatively and in fact quantitatively quite robust.
- The remain largely unchanged if:
  - We impose $\gamma = 0.5$.
  - We impose $\varrho = 0$.
  - We make the entry margin much less elastic.

Conclusion

- A new and tractable model of micro-level firm and innovation dynamics would reallocation.
- New features:
  - Endogenous exit;
  - Reallocation;
  - Selection effect.
- The model can be estimated and provides a good fit to the rich dynamics in US microdata.
- It is also useful for policy analysis.
  - Industrial policy directed at incumbents has small negative effects.
  - Optimal policy can substantially improve growth and welfare by taxing continued operation of incumbents leverage the selection effect.