Misallocation under the Shadow of Death

Daisuke Miyakawa[1] Koki Oikawa[2] Kozo Ueda[2]

[1]Hitotsubashi Univ

[2]Waseda Univ

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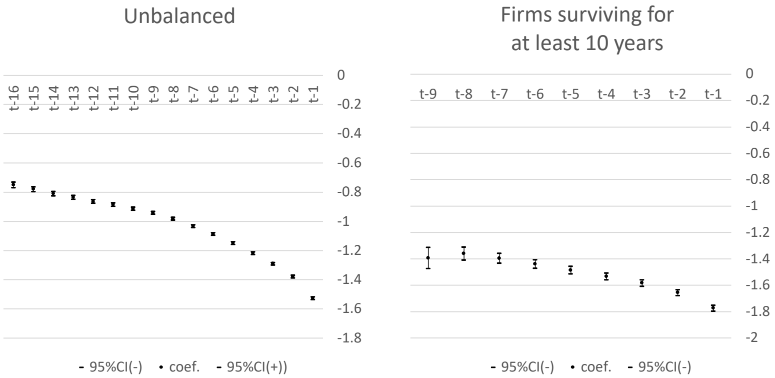
Motivations

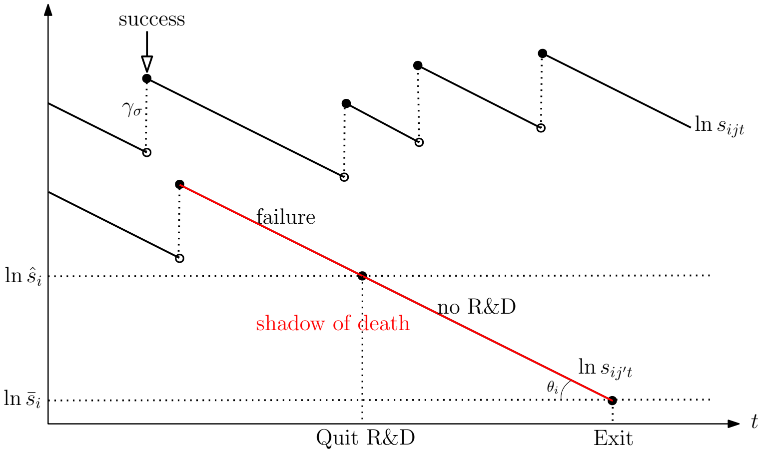
- Resource reallocation (firm dynamics) matters for macroeconomic performance
  - Entry/exit, selection (incumbents <productive $\longleftrightarrow$ unproductive firms>), ...
- We focus on slow exit, specifically, "shadow of death."
  - Declining trends in sales and productivity well before exit.
- We investigate whether and how much the aggregate productivity and welfare improve if firms destined to exit quickly exit from the market.

Empirical Preview: Pre-exit Dynamics: Sales

Sales dynamics of firms exiting at t, relative to non-exitier



Model Preview: Dynamics of Relative Productivity



What We Do

- We build an endogenous growth model with the shadow of death.
  - endogenous R&D investment and exit
    - Dynamic reallocation effect: firms with low performance have small incentive to improve their productivity
- We document facts about the shadow of death using firm-level data.
  - illustrate how sales change over time before exit and before/after R&D termination.
  - analyze how the shadow of death path is related to the external environment faced by firms.
- Simulate the effect of distortions on firm dynamics and the macroeconomy.

Main Findings

- Theoretical model
  - There exist two sales thresholds that determine exit and R&D termination.
  - A gap between the sales threshold for exit and that for R&D termination is an important indicator for the loss of optimality, proxy for the shadow of death.
  - Shortening the shadow of death improves welfare.

- Empirical facts
  - Sales of exiting firms are smaller than that of surviving firms and tend to decline, even well before their exit.
  - The degree of shadow of death has a significant relationship with the external environment faced by firms
    - such as corporate subsidies and the degree of development of the second-hand market.

- Simulation
  - The quantitative impacts of reducing distortions are limited.

Literature

- Misallocation
  - Hopenhayn & Rogerson (JPE '93); Restuccia & Rogerson (RED, '08); Hsieh & Klenow (QJE '09); etc.
  - Dynamic, rather than static, misallocation in which R&D, entry, and exit are endogenous.
- Declining business dynamism (Akcigit and Ates 2021)
  - Higher markups, lower entry and exit rates, and stagnant job creation
  - However, in Japan, market concentration is decreasing. $\rightarrow$ Focus on left-tail
- Zombie; various support measures to SMEs; aging
- Model of endogenous exits
  - Hopenhayn (ECMT 92); Luttmer (QJE 07) $\rightarrow$ R&D endogenous
  - Ericson & Pakes (RES '95); Igami & Uetake (RES '19) $\rightarrow$ Macro
- Empirical studies on the shadow of death
  - Griliches & Ragev (JE '95); Olley & Pakes (ECMT '96); Kiyota & Takizawa (RIETI '06)

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Model Setup

- In industry $i \in [0,1]$ at time t, there are n_{it} intermediate goods produced by monopolistically-competitive firms.
  - They can improve productivity by R&D investment. Fixed R&D costs, stochastic success
  - Fixed production costs.
  - Exit endogenously.
- Households
- Final-good firms

Households

- Utility:

$$\int_0^{\infty} e^{-\rho t} \ln C_t \, dt,$$

$$\ln C_t = \int_0^1 \ln Y_{it} di.$$

- Set $P_{it} Y_{it} = 1$ for any i and t.
- Inelastic labor supply, L.

Firms

- Final goods firms, $i \in [0,1]$: Perfect competition, intermediate goods as input
  - Production:

$$Y_{it} = n_{it}^{\varepsilon} \left[\int_{\mathscr{J}_{it}} x_{ijt}^{\frac{\sigma-1}{\sigma}} dj \right]^{\frac{\sigma}{\sigma-1}}, \qquad \sigma > 1, \varepsilon \in \left[-\frac{1}{\sigma-1}, 0 \right]$$

  - Demand for intermediate goods:

$$x_{ijt} = n_{it}^{\varepsilon(\sigma-1)} P_{it}^{\sigma} Y_{it} p_{ijt}^{-\sigma}$$

- Intermediate goods firms, $j \in \mathscr{J}_{it}$:
  - monopolistic competition
  - optimize R&D (productivity improvement) and exit

Intermediate Goods Firms: Production

- Production: $x_{ijt} = z_{ijt}\ell_{ijt}$
- Operational fixed cost, κ_o, in the labor unit
- Instantaneous profit

$$\max \underbrace{(p_{ijt} z_{ijt} - w_t)\,\ell_{ijt}}_{\pi_{ijt}} - \kappa_o w_t$$

$$p_{ijt} = \frac{\sigma}{\sigma - 1}\frac{w_t}{z_{ijt}}, \qquad \pi_{ijt} = \frac{s_{ijt}}{\sigma},$$

where s_{ijt} is **relative** productivity (= sales),

$$s_{ijt} \equiv \left(\frac{z_{ijt}}{Z_{it}}\right)^{\sigma-1}, \quad Z_{it} \equiv \left[\int_{\mathscr{J}_{it}} z_{ijt}^{\sigma-1} dj\right]^{\frac{1}{\sigma-1}}.$$

Intermediate Goods Firms: R&D

- Fixed R&D cost in the labor unit, κ_r.
- z_{ijt} evolves such that

$$\text{R\&D investment} \quad \Rightarrow \quad z_{ijt+dt} = \begin{cases} (1+\gamma)\, z_{ijt} & \text{w.p. } \lambda\, dt, \\ z_{ijt} & \text{w.p. } 1 - \lambda\, dt. \end{cases}$$

- The expected growth rate of relative productivity:

$$\mathrm{E}_t \frac{\dot{s}_{ijt}}{s_{ijt}} = \begin{cases} \lambda \gamma_\sigma - \theta_{it} & \text{if } \chi_{ijt} = 1, \\ -\theta_{it} & \text{if } \chi_{ijt} = 0, \end{cases} \tag{1}$$

where θ_{it} is the industry growth rate of $Z_{it}^{\sigma-1}$ and $\gamma_\sigma \equiv (1+\gamma)^{\sigma-1} - 1$.

R&D Threshold, $\hat{s}_{it}$

- HJB equation:

$$r_t v(s_{ijt}, \theta_{it}, w_t) = \max\left\{0, \frac{s_{ijt}}{\sigma} - \kappa_o w_t + \max_{\chi \in \{0,1\}} \mathrm{E}_t \left[v_s(s_{ijt}, \theta_{it}, w_t) \dot{s}_{ijt}|_{\chi=0}, -\kappa_r w_t + v_s(s_{ijt}, \theta_{it}, w_t) \dot{s}_{ijt}|_{\chi=1} \right] + v_n(s_{ijt}, \theta_{it}, w_t) \dot{\theta}_{it} + v_w(s_{ijt}, \theta_{it}, w_t) \dot{w}_t \right\}$$

- Return to R&D is increasing in s, while costs are independent of s.

Proposition

Given $\theta_{it} \geq 0$. There exists a unique threshold $\hat{s}_{it} > 0$ above which a firm invests in R&D.

$$v_s(\hat{s}_{it}, \theta_{it}, w_t)\, \hat{s}_{it} = \frac{\kappa_r w_t}{\lambda \gamma_\sigma}$$

Exit Threshold, $\bar{s}_{it}$

- $v(\bar{s}_{it}, \theta_{it}, w_t) = 0$ & $v_s(\bar{s}_{it}, \theta_{it}, w_t) = 0$ imply

$$0 = \frac{\bar{s}_{it}}{\sigma} - \kappa_o w_t + v_\theta(\bar{s}_{it}, \theta_{it}, w_t)\dot{\theta}_{it} + v_w(\bar{s}_{it}, \theta_{it}, w_t)\dot{w}_t$$

Proposition

In a stationary state with a given $\theta > 0$, the thresholds for exit and R&D are uniquely determined and satisfy

$$\bar{s} = \sigma \kappa_o w = \frac{(\sigma - 1)\kappa_o}{L_X}, \tag{2}$$

$$\frac{1}{r+\theta}\left(\frac{\hat{s}}{\bar{s}} - \left(\frac{\hat{s}}{\bar{s}}\right)^{-\frac{r}{\theta}}\right) = \frac{\kappa_r/\kappa_o}{\lambda \gamma_\sigma}. \tag{3}$$

Moreover, $\hat{s}$ is increasing in θ, ceteris paribus.

- The duration of non-R&D investment, $\hat{s}/\bar{s}$, corresponds to the shadow of death, since such a firm is deemed to exit.

Stationary Equilibrium

- Stationary distribution, F_i
- Stationary equilibrium: $\{\bar{s}_i, \hat{s}_i, n_i, \theta_i, \mu_i, \delta_i\}_{i\in[0,1]}$ and w that satisfy
  - Households' optimization: consumption
  - Firm's optimization: production, R&D, exit
  - Free entry: fixed entry cost, κ_e, in the labor unit.
  - Labor market clearing

Equilibrium Shadow of Death is Inefficient

- Inefficiency in R&D decision making
  - Under a high industry-level R&D intensity, the relative productivity advantage gained by R&D success will soon disappear. This reduces the R&D incentive from the private viewpoint.
  - By contrast, the social planner looks at absolute productivity that determines output and consumption.
- Thus, underinvestment in R&D

Proposition

The market equilibrium has a wider range of firms that are not engaged in R&D,

$$\frac{\hat{s}}{\bar{s}} > \frac{\hat{s}^*}{\bar{s}^*}.$$

- Also, inefficiency due to intertemporal knowledge spillover exists.
  - New entrants draw relative productivity s, not absolute productivity z.

Exit Distortions

- Inefficiency is enlarged when we have distortions that increase $\hat{s}/\bar{s}$.
- Exit distortion $1-\tau$
$$\bar{s} = \tau\sigma\kappa_o w,$$
which also influences $\hat{s}$.
  - $\tau_{ij} = 1$ indicates no distortion.
- Examples
  - Government (size-dependent) subsidy to a firm, $K > 0$: $\tau = 1 - \frac{K}{\kappa_o w}$.
  - Decrease in outside option value, $\xi < 0$: $\tau = 1 + \frac{r\xi}{\kappa_o w}$.

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TSR Data

- We provide empirical facts on the shadow of death using firm-level data for Japan; through this, we aim to check whether our model is consistent with the data.
- Firm-level data by TSR
  - TSR is one of the largest credit rating companies in Japan
- Sales from 2001 to 2019 and exits from 2008 to 2019
- The number of firm observation is around 0.8 to 0.9 million per year.
  - cover more than 20% of all firms.
- Focus on closure and dissolution, which we name as "voluntary closure."
  - Reasons for firm exit are classified to closure, dissolution, bankruptcy (default), merger, or others. Explain around 90% of total exit records.

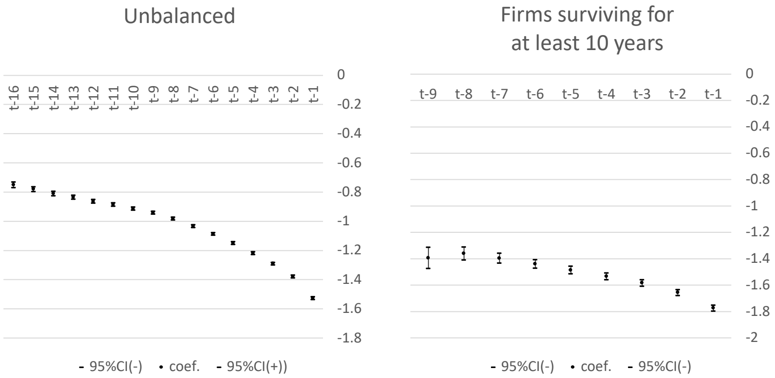
Estimation for Pre-exit Dynamics

- Dynamics of firm size measured by log(sales)
  - Exit = voluntary closure
  - As of h-year prior to exit timing

$$\log\left(\text{sales}_{j,t}\right) = \alpha + \sum_{h=0}^{H} \beta_h \mathbb{1}\left(\text{exit}_{j,t+h}\right) + \eta_{I_j,t} + \varepsilon_{j,t}, \tag{4}$$

  - ★ $\alpha + \eta_{I_j,t}$: Average sales of non-exiting firms in industry I_j in t.
  - ★ β_h: How much "eventually-exiting firms" are smaller than the average of non-exiting firms as of h years prior to its exit

Pre-exit Dynamics: Sales



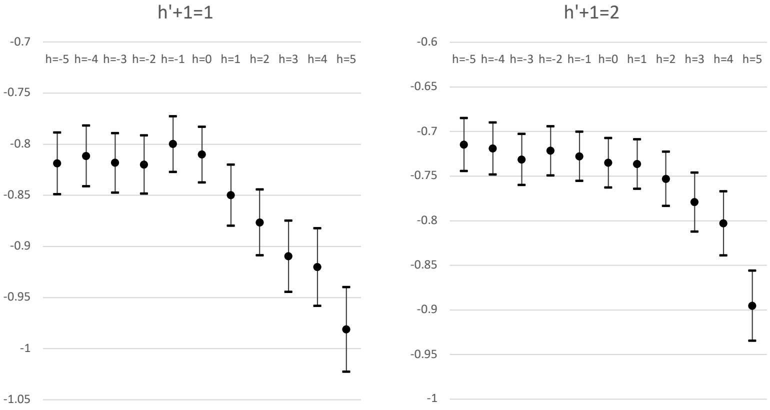
R&D Investment and Firm Dynamics

- What happens before/after a firm ends efforts to improve its performance by R&D?

$$\log(\text{sales}_{j,t}) = \gamma + \delta_h \mathbb{1}\left(R\&D_{j,t-h,t-h+h'} = 0\right) + \eta_{I_j,t} + \varepsilon_{j,t}. \qquad (5)$$

  - R&D lumpy: we consider that a firm stops R&D when it does not make R&D investment for a certain duration ($h' + 1$ years).
  - $\gamma + \eta_{I_j,t}$: Average sales size of R&D firms in t.
  - δ_h: How much sales declines before/after R&D termination.

Sales Drop after R&D Stoppage



Distortions and the Shadow of Death

- Distortions: industry-level time-variant
  - Subsidy: IO table
  - Captial resalability: SNA
- Equations regressed

$$\log\left(\text{sales}_{j,t}\right) = \alpha + \beta_h \mathbb{1}\left(\text{exit}_{j,t+h}\right) + \beta_h^D \mathbb{1}\left(\text{exit}_{j,t+h}\right) \times \text{distortion}_{I_j,t} + \eta_{I_j,t} + \varepsilon_{i,t}, \quad (6)$$

$$\log\left(\text{sales}_{j,t}\right) = \gamma + \delta_h \mathbb{1}\left(R\&D_{j,t-h,t-h+h'} = 0\right) + \delta_h^D \mathbb{1}\left(R\&D_{j,t-h,t-h+h'} = 0\right) \times \text{distortion}_{I_j,t} + \eta_{I_j,t} + \varepsilon_{j,t}. \quad (7)$$

- $\beta_h^D - \delta_h^D$ is negative if distortions increase the degree of the shadow of death.

Table: Distortions and Firm Dynamics

(i) Distortion: Net subsidy/Value-added												
	Pre-exit dynamics						Pre/post-R&D termination dynamics					
	$h=1$			$h=3$			$h=-1$, $h'=1$			$h=1$, $h'=1$		
	Coef.	s.e.		Coef.	s.e.		Coef.	s.e.		Coef.	s.e.	
β_h	-1.393	0.011	***	-1.278	0.012	***						
β_h^D	-0.401	0.134	***	-0.492	0.148	***						
δ_h							-0.889	0.021	***	-0.934	0.023	***
δ_h^D							0.416	0.204	**	0.544	0.219	**
Fixed-effect												
Year×Industry	yes			yes			yes			yes		
Number of observations	9,064,930			6,983,006			80,344			70,021		
Prob>F	0.0000			0.0000			0.0000			0.0000		
Adj R-squared	0.1585			0.1373			0.3810			0.3844		

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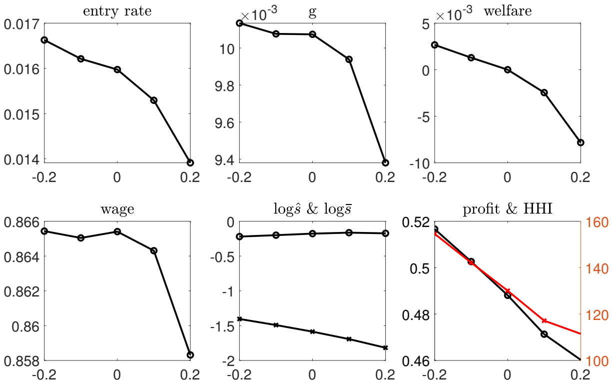
Calibration

- Simulate the effects of distortions
  - Calibrate the model to the Japanese economy based on the TSR data
  - Key parameters such as $\lambda = 0.037$, $\bar{\delta} = 0.0028$, $\gamma = 0.11$, $\kappa_o = 0.055$, and $\kappa_r = 0.035$.

		Data	Simulation
Targeted moments			
	Prob. of sales share increase for R&D firms	0.037	0.037
	Prob of exit for R&D firms	0.0028	0.0028
	Entry rate	0.006 (0.051)	0.016
	Share of fixed costs in sales	0.050	0.047
	Share of R&D costs in sales for R&D firms	0.028	0.030
	Ratio of R&D threshold to exit threshold	4.080	4.091
Untargeted moments			
	Ratio of the mean of sales of all firms to entrants	0.971	0.667
	Ratio of the SD of sales of all firms to entrants	0.534	0.691
	Speed of sales change for non R&D firms	-0.040	-0.033

Results

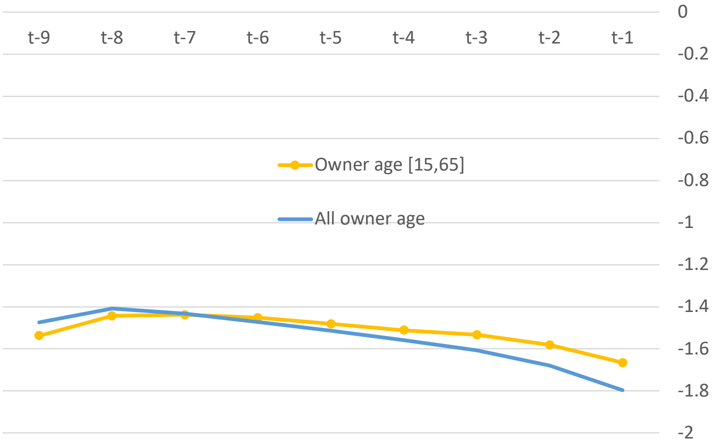
- Horizontal axis: distortion $1-\tau$ (subsidy to firms below $\hat{s}$)
- Distortion increases the gap $\hat{s}/\bar{s}$ and worsens welfare.
    - entry decreases; profit and HHI decrease; g decreases.
- However, quantitatively small effects.



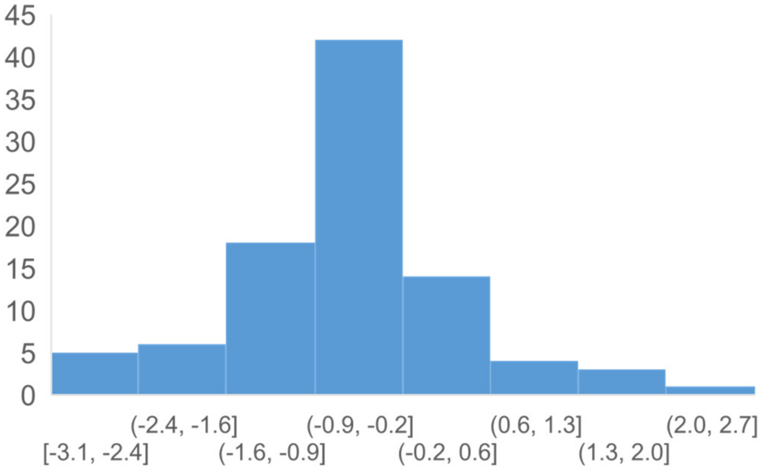
Final Notes

- Effects on R&D and real growth turn out to be small.
- Transition
- Superstar firms

Robustness: Owner's Age



Dispersion of Exit Thresholds



Note: The horizontal axis indicates $\bar{s}$ over fixed costs, where $\bar{s}$ is calculated as $\exp(\beta_1 + \alpha)$ for the regression of equation (4). The vertial axis is the number of industries.

Table: Distortions and Firm Dynamics

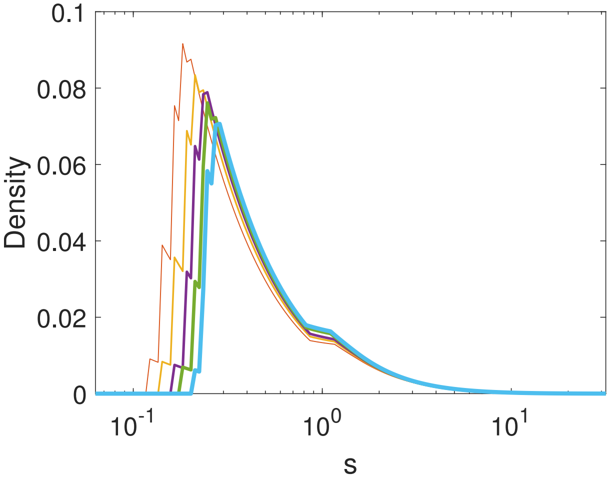
(i) Distortion: Net subsidy/Value-added

	Pre-exit dynamics						Pre/post-R&D termination dynamics					
	$h=1$			$h=3$			$h=-1, h'=1$			$h=1, h'=1$		
	Coef.	s.e.		Coef.	s.e.		Coef.	s.e.		Coef.	s.e.	
β_h	-1.393	0.011	***	-1.278	0.012	***						
β_h^D	-0.401	0.134	***	-0.492	0.148	***						
δ_h							-0.889	0.021	***	-0.934	0.023	***
δ_h^D							0.416	0.204	**	0.544	0.219	**
Fixed-effect												
Year×Industry	yes			yes			yes			yes		
Number of observations	9,064,930			6,983,006			80,344			70,021		
Prob>F	0.0000			0.0000			0.0000			0.0000		
Adj R-squared	0.1585			0.1373			0.3810			0.3844		

(ii) Distortion: Capital investment on used assets / Total capital investment

	Pre-exit dynamics						Pre/post-R&D termination dynamics					
	$h=1$			$h=3$			$h=-1, h'=1$			$h=1, h'=1$		
	Coef.	s.e.		Coef.	s.e.		Coef.	s.e.		Coef.	s.e.	
β_h	-1.493	0.018	***	-1.421	0.019	***						
β_h^D	0.259	0.067	***	0.494	0.073	***						
δ_h							-1.305	0.036	***	-1.332	0.039	***
δ_h^D							1.269	0.154	***	1.181	0.166	***
Fixed-effect												
Year×Industry	yes			yes			yes			yes		
Number of observations	4,756,232			3,577,931			49,401			43,321		
Prob>F	0.0000			0.0000			0.0000			0.0000		
Adj R-squared	0.1393			0.1420			0.3614			0.3633		

Results: Firm-size Distribution



Note: Firm distribution is drawn for various values of subsidy $(1-\tau)$, where the horizontal axis is sales s. The line width becomes thinner as subsidy increases.

Table: Relations between the RD Frequency and the Exit Probability and Sales Growth

	Definition of R&D		
	R&D	Selling, general, and administrative (SGA) expenses	Sales promotion, advertising, entertainment, and other selling expenses
Number of firms			
All	4,236,113	4,236,113	4,236,113
R&D expenditure is not NA (A)	701,763	701,763	701,763
Zero R&D expenditure throughout	659,815	105,027	190,182
R&D expenditure is positive at least once (B)	41,948	596,736	511,581
(fraction, B/A)	(0.060)	(0.850)	(0.729)
Voluntary exit rate (the number of voluntary exit firms divided by the total number of firms)			
Probability of positive R&D			
Zero	0.032	0.045	0.044
Positive and 0 to 25%	0.012	0.045	0.041
25% to 50%	0.021	0.034	0.030
50% to 75%	0.017	0.022	0.020
75% -	0.014	0.014	0.014
Fraction of firms with positive average sales growth			
Probability of positive R&D			
Zero	0.469	0.460	0.440
Positive and 0 to 25%	0.516	0.419	0.429
25% to 50%	0.544	0.450	0.462
50% to 75%	0.584	0.485	0.488
75% -	0.614	0.554	0.573