Online Appendix: Firm Selection and Corporate Cash Holdings

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Abstract

Since the early 1980s, the composition of US public firms has progressively shifted toward less profitable firms with high growth potential (Fama and French, 2004). We estimate a dynamic corporate finance model to quantify the role of this selection mechanism for the secular trend in cash holdings among US public firms. We find that an increase in the precautionary savings motive—primarily driven by the decline in initial profitability among R&D-intensive new lists—explains about 50% of the upward trend in cash holdings. This selection mechanism also explains part of the upward trend in sales growth volatility.

Keywords: Cash holdings, R&D firms, New lists, Firm selection

JEL Codes: G30, G32

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[1]We especially thank an anonymous referee, Toni Whited (editor), Joan Farre-Mensa, and Rebecca Wasyk for comments and suggestions. Youngmin Kim provided excellent research assistance. We are also grateful to Rajesh Aggarwal, Rui Albuquerque, Simcha Barkai, Philip Bond, Andrea Buffa, Gian Luca Clementi, Marco Da Rin, Antonio Falato, Fritz Foley, Ron Giammarino, Ambrus Kecskes, Pablo Kurlat, Oliver Levine, Evgeny Lyandres, Mamdouh Medhat, Sebastien Michenaud, Stefano Sacchetto, Martin Schmalz, Ken Singleton, Viktoriya Staneva, Anna-Leigh Stone, Sheridan Titman, and Bektemir Ysmailov as well as seminar attendants at Boston University, Harvard University, IDC Summer Conference, SED meeting in Warsaw, Tepper-LAEF Conference on "Advances in Macro-Finance", Christmas meeting at LMU, Utah Winter Finance Conference, Midwest Finance Association Conference, SUNY at Stony Brook, World Finance Conference, Federal Reserve Board, D'Amore-McKim School of Business, Simon School of Business, Carlson School of Management Finance Department Junior Conference, Driehaus College of Business, SFS Cavalcade, Western Finance Association, UBC Summer Finance Conference, European Finance Association, American Finance Association, and American Economic Association for their comments and suggestions. All remaining errors are our own responsibility. The views expressed are those of the authors and do not necessarily reflect those of the Federal Reserve Board or the Federal Reserve System.

Appendix A. Data description

We use annual Compustat data for the period 1959-2013, excluding financial firms (SIC codes 6000 to 6999) and regulated industries (SIC codes 4000 to 4999), non-US-incorporated firms, and those not traded on the three major exchanges: NYSE, Amex, and Nasdaq (exchange codes 11, 12, and 14).

We want to follow the dynamics of an entering cohort. To this end, we sort firms into seven cohorts using non-overlapping periods of five years starting with the window 1979-1983. A cohort definition based on a five-year window is fairly standard in the firm dynamics literature but is not essential to our results. We define an entrant as a firm that reports a year-end value of the stock price for the first time (item *PRCC_C*). We normalize the age of an entrant to one.

A.1. R&D-intensive firms

R&D-intensive firms are firms that belong to an industry (using the three-level-digit SIC code) that have an average R&D investment-to-assets ratio of at least 2%. We choose 2% as the cut-off level because it is the minimum R&D-to-asset ratios of the top quintile industries in terms of R&D to assets.

Our R&D–based industry classification is consistent with other classifications used in previous empirical studies. The seven industries that account for the bulk of R&D-intensive entrants are the same industries Brown, Fazzari, and Petersen (2009) use to identify the high-tech sector. In addition, our broadly defined R&D-intensive sector contains all the industries classified as "Internet and technology firms" by Loughran and Ritter (2004), with the exception of Telephone equipment (SIC 481), which we exclude by construction because it belongs to a regulated industry.[2]

A.2. Moments calculations

We calculate 13 moments from four accounting ratios: cash-to-assets, sales growth rate, investment-to-assets, and equity issuance-to-assets. The cash-to-assets ratio is cash and cash equivalents (Compustat item *che*) divided by total assets (item *at*). To calculate a firm's sales growth rate, we first eliminate the effect of inflation and aggregate growth by dividing a firm's sales (item *sale*) at time t by the corresponding time t level of nominal GDP; we call this scaled variable *rsale*. Then, we define the real sales growth rate between time $t-1$ and t as $\Delta rsale_t = \frac{rsale_t - rsale_{t-1}}{0.5 rsale_{t-1} 0.5 rsale_{t-1}}$. The investment-to-asset ratio is the difference in net property, plant, and equipment (item *ppent*) between two consecutive periods divided by total assets (item *at*). The equity issuance-to-assets ratio is sale of common and preferred stock (item *sstk*) divided by total assets (item *at*).[3] Table A.2 reports the accounting ratios in the data and their counterparts in the model.

Table A.2
Quantities: model versus data

	model	data
cash-to-asset	$c_t/(c_t+k_t)$	che_t/at_t
sales growth	$\frac{y_t - y_{t-1}}{0.5y_t + 0.5y_{t-1}}$	$\frac{rsale_t - rsale_{t-1}}{0.5rsale_t + 0.5rsale_{t-1}}$
investment-to-asset	$x_{t+1}/(c_t+k_t)$	$(ppent_{t+1} - ppent_t)/at_t$
equity-to-assets	$\frac{d_t \mathbf{1}_{[d_t \leq 0]}}{(c_t+k_t)}$	$\frac{sstk_t}{a_t}$

[2]Differently from Bates, Kahle, and Stulz (2009), we do not follow the classification in Loughran and Ritter (2004) because it excludes one of the most relevant R&D-intensive industries (Drugs, SIC 283) from the R&D-intensive sector. We obtain very similar results if we narrow our definition down to using the seven specific industries that account for the bulk of R&D-intensive entrants: Computer and data processing services (SIC 737, 26% of total entrants), Drugs (SIC 283, 15%), Medical instruments and supplies (SIC 384, 9%), Electronic components and accessories (SIC 367, 8%), Computer and office equipment (SIC 357, 7%), Measuring and controlling devices (SIC 382, 5%), and Communications equipment (SIC 366, 5%).

[3]To focus only on equity issuances for financing purposes (as opposed to, e.g., for compensation purposes), we follow McKeon (2013) and only consider equity issues with proceeds exceeding 3% of the firm's market equity value. The latter quantity is defined as common shares outstanding (item *csho*) times market price at the calendar year end (item *prcc_c*).

To calculate the 13 moments used in the estimation, we rely on balanced panels of firms of length ten years across different cohorts and industries. Each firm in the panel has ten consecutive years of observations on total assets (item *at*); cash and cash equivalents (item *che*); sales (item *sale*); net property, plant, and equipment (item *ppent*); sale of common and preferred stock (item *sstk*); common shares outstanding (item *csho*); and market price at the calendar year end (item *prcc_c*). For each panel, we calculate the following moments:

- Average cash holdings at entry: the average value of the cash-to-asset ratio for companies of age one (i.e., for the first year a company reports a value for the market price at the calendar year end (item *prcc_c*)).
- Average change in cash holdings: the average of the firm-level difference between the cash-to-asset ratio at age ten and the cash-to-asset at age one (i.e., at entry).
- Volatility of cash holdings: the average of the firm-level cash-to-asset ratio's standard deviation calculated using data from age one to age ten.
- Autocorrelation of cash holdings: the average of the firm-level cash-to-asset ratio's autocorrelation calculated using ten years of data. The autocorrelation coefficient is the coefficient β in the linear regression $\frac{che_{i,t}}{at_{i,t}} = \alpha + \beta \frac{che_{i,t-1}}{at_{i,t-1}} + \varepsilon_{i,t}$.
- Average issue size at year ten: the average equity issuance-to-asset calculated at age ten.
- Mean sales growth at two: the average sales growth rate of firms of age two.
- Volatility of sales growth at entry: the cross-sectional dispersion in firm-level growth rates among firms of age two.
- Average change in sales growth: the average of the firm-level difference between the sales growth rate at age ten and the sales growth rate at age two.
- Volatility of sales growth: the average of the firm-level sales growth rate's standard deviation calculated using ten years of data.
- Autocorrelation of sales growth: the average of the firm-level sales growth rate's autocorrelation calculated using nine years of data. The autocorrelation coefficient is the coefficient β in the linear regression $\Delta rsale_{i,t} = \alpha + \beta \Delta rsale_{i,t-1} + \varepsilon_{i,t}$.
- Average investment rate at entry: the average value of the investment-to-asset ratio at age one.
- Average change in investment rate: the average of the firm-level difference between the investment-to-asset ratio at age ten and the investment-to-asset ratio at age two.
- Volatility of investment rate: the average of the firm-level investment-to-asset ratio's standard deviation calculated using ten years of data.

All quantities are winsorized at the top and bottom 1%.

Appendix B. Supplemental empirical results

B.1. Selection effect versus within effect

Table B.1 reports the contribution of the selection effect and of the within change on a year-by-year basis for the period 1979–2012. For each year, we report both the change and the cumulative change in average cash holdings due to incumbents (within change) and the change in average cash holdings due to the selection effect. The latter quantity is split between the selection effect generated by R&D-intensive firms and the selection effect generated by non-R&D-intensive firms. The average cash holdings equal 0.087 in 1978 and 0.238 in 2012, an increase of 0.151. We can decompose the actual increase in the contribution of the within change and the contribution of the selection effect. The within-change contribution is -0.190, whereas the overall contribution of the selection effect is 0.342.

In Table B.1, we decompose the cash trend at the three-digit SIC code industry level. The two sectors that play a key role in determining the selection effect are Drugs (SIC 283) and Computer and data processing services (SIC 737). On their own, they explain around 50% of the overall selection effect, whereas the remaining five R&D-intensive sectors identified by Brown, Fazzari, and Petersen (2009) account for 25%. When we consider all the industries, the R&D-intensive sector accounts for the bulk (82%) of the selection effect.

Table B.1
Cash change decomposition

	Change				Cumulative change				Average
Year	Within	R&D	Non-R&D	Total	Within	R&D	Non-R&D	Total	All firms
1979	-0.006	0.003	0.000	-0.003	-0.006	0.003	0.000	-0.003	0.088
1980	0.001	0.004	0.001	0.006	-0.006	0.007	0.001	0.002	0.107
1981	0.004	0.011	0.004	0.019	-0.002	0.018	0.005	0.021	0.113
1982	-0.002	0.007	0.001	0.006	-0.004	0.024	0.006	0.027	0.152
1983	0.013	0.019	0.008	0.040	0.009	0.044	0.014	0.067	0.143
1984	-0.027	0.015	0.002	-0.010	-0.018	0.059	0.016	0.057	0.137
1985	-0.012	0.003	0.003	-0.006	-0.030	0.062	0.019	0.051	0.154
1986	-0.002	0.014	0.005	0.017	-0.032	0.076	0.024	0.068	0.156
1987	-0.012	0.011	0.003	0.002	-0.044	0.087	0.027	0.070	0.143
1988	-0.018	0.003	0.002	-0.01d3	-0.062	0.090	0.029	0.057	0.141
1989	-0.004	0.003	-0.001	-0.002	-0.067	0.094	0.028	0.055	0.144
1990	-0.009	0.010	0.001	0.003	-0.076	0.104	0.030	0.058	0.166
1991	-0.003	0.020	0.004	0.022	-0.079	0.125	0.034	0.080	0.173
1992	-0.019	0.021	0.006	0.008	-0.098	0.146	0.040	0.088	0.179
1993	-0.023	0.022	0.006	0.006	-0.121	0.168	0.046	0.093	0.166
1994	-0.030	0.012	0.005	-0.013	-0.151	0.180	0.051	0.080	0.176
1995	-0.016	0.020	0.005	0.010	-0.166	0.200	0.056	0.090	0.204
1996	-0.014	0.035	0.007	0.029	-0.180	0.236	0.063	0.118	0.208
1997	-0.014	0.013	0.004	0.004	-0.194	0.249	0.067	0.122	0.198
1998	-0.010	0.001	0.000	-0.009	-0.204	0.249	0.067	0.113	0.210
1999	-0.007	0.019	0.000	0.012	-0.211	0.269	0.067	0.125	0.229
2000	-0.007	0.026	0.000	0.019	-0.218	0.294	0.068	0.144	0.236
2001	0.011	-0.004	-0.001	0.006	-0.207	0.291	0.066	0.150	0.235
2002	0.008	-0.007	-0.001	0.000	-0.199	0.284	0.065	0.150	0.248
2003	0.019	-0.006	-0.001	0.012	-0.180	0.277	0.064	0.162	0.257
2004	0.000	0.008	0.002	0.009	-0.180	0.285	0.066	0.171	0.257
2005	-0.002	0.001	0.001	0.000	-0.182	0.286	0.067	0.171	0.253
2006	-0.005	0.000	0.002	-0.003	-0.187	0.286	0.068	0.167	0.252
2007	-0.005	0.003	0.001	-0.001	-0.192	0.289	0.069	0.166	0.227
2008	-0.015	-0.009	-0.001	-0.025	-0.207	0.280	0.068	0.141	0.245
2009	0.026	-0.008	0.000	0.018	-0.181	0.272	0.068	0.159	0.251
2010	0.007	0.001	-0.002	0.006	-0.174	0.273	0.066	0.165	0.242
2011	-0.009	0.002	-0.002	-0.009	-0.183	0.275	0.065	0.156	0.237
2012	-0.007	0.004	-0.002	-0.005	-0.190	0.279	0.063	0.151	0.238

This table reports the year-by-year decomposition of the cash-to-assets ratio over the period 1979–2012. We report both the yearly change and the cumulative change. The column wihin reports the contribution of incumbent firms. The column R&D reports the contribution of R&D-intensive net entrants. The column Non-R&D reports the contribution of non-R&D-intensive net entrants. The last column reports the average cash-to-assets ratio.

Table B.1
Selection effect by sectors

Industries	Selection effect	Percentage
Drugs (SIC 283)	0.087	25.24%
Computer and data processing services (SIC 737)	0.077	22.51%
Medical instruments and supplies (SIC 384)	0.033	9.52%
Electronic components and accessories (SIC 367)	0.021	6.06%
Computer and office equipment (SIC 357)	0.015	4.52%
Measuring and controlling devices (SIC 382)	0.010	2.92%
Communications equipment (SIC 366)	0.009	2.71%
Other R&D-intensive industries	0.028	8.16%
R&D-intensive sector	0.280	81.63%
Non-R&D-intensive sector	0.063	18.37%
Selection effect	0.343	100.00%

This table reports the contribution of different R&D-intensive industries to the selection effect. The results are derived performing the following selection-effect decomposition:

$$\sum_i \Big(\frac{N_t^{E_i}}{N_t} CH_t^{E_i} - \frac{N_{t-1}^{X_i}}{N_{t-1}} CH_{t-1}^{X_i} \Big),$$

where i={Drugs; Computer and data processing services; Medical instruments and supplies; Electronic components and accessories; Computer and office equipment; Communications equipment; Measuring and controlling devices; Other R&D-intensive industries; non-R&D-intensive sector}. The reported number is cumulative changes over the period 1979-2013.

B.2. *Value-weighted results*

Table B.2 presents the same decomposition exercise as above but with the value-weighted instead of the equally weighted cash-to-assets ratio. In this case, we decompose the change in the value-weighted cash-to-assets ratio between time $t-1$ and t as

$$\Delta CH_t^{VW} = \underbrace{\sum_{i=1}^{I_t}(w_{i,t}CH_{i,t} - w_{i,t-1}CH_{i,t-1})}_{\text{within change}} + \underbrace{\sum_{j=1}^{E_t} w_{j,t}CH_{j,t} - \sum_{k=1}^{X_{t-1}} w_{k,t-1}CH_{k,t-1}}_{\text{selection effect}},$$

where the first term is the change in average cash holdings due to incumbents (within change), and the second term is the change in average cash holdings due to the selection effect. I_t denotes the number of incumbents in the sample between time $t-1$ and t, E_t denotes the number of entrants in the sample at time t, and X_{t-1} denotes the number of firms that exit the sample at the end of time $t-1$. The weight is given by the value of the firm at time t over the total value of the firms in the sample at time t. We measure the firm's value as the sum of total liabilities (Compustat item *LT*) and market value of equity, which is calculated as the product of the number of shares outstanding (Compustat item *CSHO*) times the price per share (Compustat item *PRCC_C*).

As in the equally weighted case, R&D-intensive entrants play a key role in shaping the time-series evolution of the value-weighted cash-to-assets ratio. However, value weighting sheds a different light on the phenomenon itself. When we consider all the firms in the sample, the within effect and the selection effect due to R&D-intensive entrants have roughly the same importance in explaining how the value-weighted cash-to-assets ratio evolves over time. This is driven by firms in the top 1% of the size distribution. Excluding these firms from the sample makes the selection effect the most important driving force. The top 1% of firms are large multinationals for whom cash holdings are largely dominated by tax consideration of international income (see Foley et al., 2007).

B.3. *Exit margin*

Fig. B.3 compares the average cash holdings of entering and exiting firms in our sample. The data show that exitors hold almost the same cash ratio as the average firm over time, supporting the assumption of an exogenous and i.i.d. exit process used in the model.

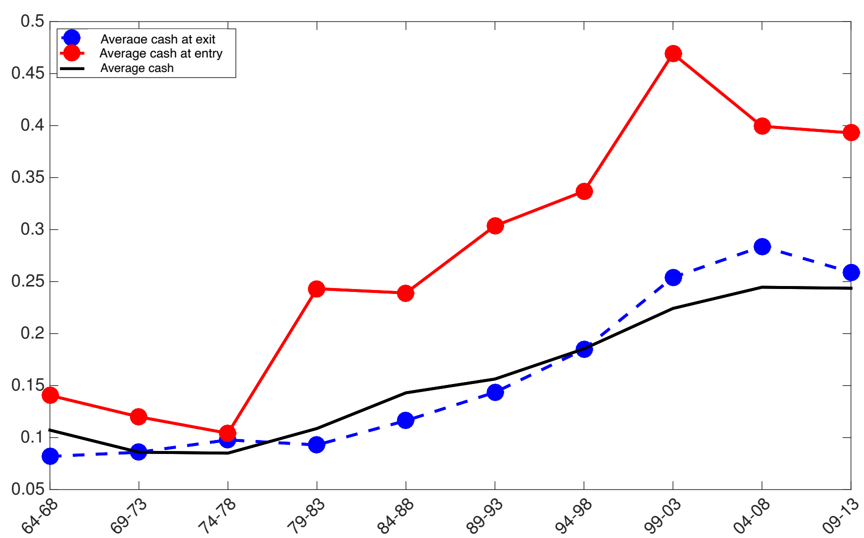

Fig. B.3. Average cash-to-assets ratio at entry and at exit of US-listed firms
This figure reports the average cash-to-assets ratio at entry (solid dotted red line) versus at exit (dashed-dotted blue line) as well as the average cash-to-asset ratio of the sample (solid black line). We group firms into cohorts of five years starting with the cohort 1964-1968 and ending with the cohort 2009-2013.

Table B.2
Value-weighted cash change decomposition

	All firms				Excluding top 1%				Excluding top 5%			
Year	CH	Within	Select. R&D	Select. no-R&D	CH	Within	Select. R&D	Select. no-R&D	CH	Within	Select. R&D	Select. no-R&D
1979	0.08	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.07	0.00	0.00	0.00
1980	0.07	-0.01	0.00	0.00	0.07	0.00	0.00	0.00	0.07	0.01	0.00	0.00
1981	0.07	-0.01	0.00	0.00	0.07	0.00	0.00	0.00	0.08	0.01	0.00	-0.01
1982	0.07	-0.01	0.00	0.00	0.08	0.01	0.00	0.00	0.08	0.02	0.01	-0.01
1983	0.09	0.01	0.01	0.00	0.11	0.03	0.01	0.00	0.12	0.04	0.02	-0.01
1984	0.08	0.00	0.01	-0.01	0.09	0.01	0.01	-0.01	0.11	0.03	0.02	-0.01
1985	0.08	0.00	0.00	-0.01	0.09	0.01	0.01	-0.01	0.11	0.03	0.02	-0.01
1986	0.09	0.01	0.01	-0.01	0.09	0.02	0.01	-0.01	0.12	0.04	0.02	-0.01
1987	0.09	0.01	0.01	-0.01	0.09	0.02	0.01	-0.01	0.12	0.03	0.03	-0.01
1988	0.07	-0.01	0.01	-0.01	0.08	0.00	0.01	-0.01	0.10	0.02	0.03	-0.01
1989	0.07	-0.01	0.00	-0.01	0.08	0.00	0.00	-0.01	0.10	0.02	0.02	-0.01
1990	0.07	-0.01	0.01	-0.01	0.08	0.00	0.01	-0.01	0.10	0.02	0.02	-0.01
1991	0.08	-0.01	0.01	-0.01	0.10	0.02	0.01	-0.01	0.13	0.04	0.03	-0.01
1992	0.08	0.00	0.01	-0.01	0.10	0.02	0.01	-0.01	0.12	0.03	0.03	-0.01
1993	0.08	-0.01	0.01	0.00	0.10	0.01	0.02	0.00	0.12	0.03	0.04	-0.01
1994	0.08	-0.01	0.01	0.00	0.09	0.01	0.01	0.00	0.11	0.01	0.04	-0.01
1995	0.09	0.00	0.01	0.00	0.10	0.01	0.01	0.00	0.13	0.02	0.05	0.00
1996	0.10	0.00	0.02	0.00	0.10	0.01	0.02	0.00	0.14	0.01	0.06	0.00
1997	0.11	0.01	0.02	0.00	0.10	0.01	0.02	0.00	0.13	0.00	0.06	0.00
1998	0.12	0.02	0.02	0.00	0.11	0.01	0.02	0.00	0.13	0.00	0.06	0.00
1999	0.17	0.05	0.04	0.00	0.19	0.05	0.06	0.00	0.21	0.03	0.11	0.00
2000	0.17	0.04	0.05	0.00	0.17	0.02	0.08	0.00	0.20	-0.01	0.14	0.00
2001	0.16	0.03	0.05	0.00	0.15	0.00	0.08	0.00	0.18	-0.02	0.13	0.00
2002	0.14	0.02	0.05	0.00	0.13	-0.02	0.08	0.00	0.15	-0.05	0.13	0.00
2003	0.16	0.04	0.04	0.00	0.16	0.01	0.08	0.00	0.17	-0.02	0.13	0.00
2004	0.18	0.05	0.05	0.00	0.16	0.01	0.08	0.00	0.17	-0.03	0.13	0.00
2005	0.18	0.05	0.05	0.00	0.16	0.02	0.07	0.00	0.17	-0.03	0.13	0.00
2006	0.16	0.04	0.04	0.00	0.15	0.01	0.07	0.00	0.16	-0.03	0.12	0.00
2007	0.16	0.04	0.04	-0.01	0.14	0.00	0.07	0.00	0.16	-0.03	0.12	0.00
2008	0.14	0.02	0.04	0.00	0.13	-0.01	0.06	0.00	0.14	-0.05	0.12	0.00
2009	0.17	0.05	0.04	0.00	0.15	0.02	0.06	0.00	0.17	-0.02	0.12	0.00
2010	0.17	0.05	0.04	0.00	0.16	0.03	0.06	0.00	0.18	-0.01	0.12	0.00
2011	0.17	0.05	0.04	0.00	0.16	0.03	0.06	0.00	0.17	-0.02	0.12	0.00
2012	0.16	0.04	0.04	0.00	0.15	0.02	0.07	-0.01	0.16	-0.03	0.12	0.00
	0.08	48%	57%	-5%	0.08	20%	87%	-7%	0.09	-29%	131%	-2%

This table reports the year-by-year decomposition of the value-weighted cash-to-assets ratio over the period 1979–2012. We perform the decomposition using (i) all the firms in the sample, (ii) excluding firms in the top 1% of the size distribution, and (iii) excluding firms in the top 5% of the size distribution. For each sample, we report the value-weighted cash-to-asset ratio (Column *CH*), the cumulative change due to incumbent firms (Column Within), the cumulative selection effect due to R&D-intensive firms (Column Select. R&D), and the cumulative selection effect due to non-R&D-intensive firms (Column Select. no-R&D). The last row reports the cumulative change in the value-weighted cash-to-assets ratio over the period 1979–2012 and the corresponding contribution (in percentage terms) of the within and the selection effects.

B.4. Cash around IPO

Fig. B.4 reports average cash holdings of firms a year before the IPO, around the IPO, and after the IPO. Note that the trend in cash holdings is present even before firms go public, suggesting a mechanism beyond merely higher cash holdings through IPO proceeds.

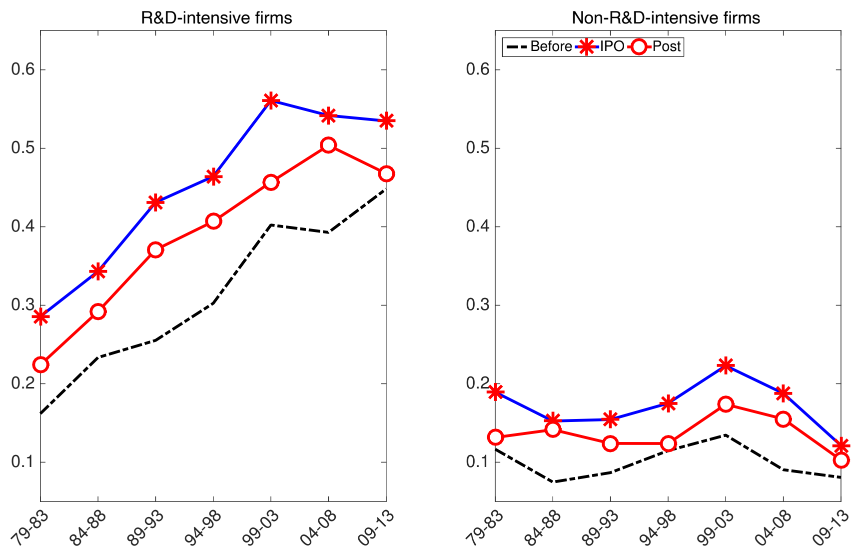

Fig. B.4. Pre-IPO cash holdings
This figure reports the average cash-to-asset ratio one year before the IPO (*Before*), the year of the IPO (*IPO*), and the year after the IPO (*Post*) for R&D–intensive firms (left panel) and non-R&D-intensive firms (right panel).

Appendix C. Model's solution and estimation

C.1. Incumbent and entrant problem

We solve the incumbent problem by value function iteration. We discretize the firm-level shock with 35 grid points using the method in Rouwenhorst (1995). We discretize both the capital grid and the cash grid using the method in McGrattan (1999), and we choose 50 grid points for capital and 20 grid points for cash. For each iteration of the value function and for each choice of next-period capital stock (k'), we calculate the optimal cash policy (c') via a golden-search algorithm. We calculate the optimal capital choice k' and the corresponding optimal retention policy c' for each possible state (k, c, z). We keep iterating on the value function until $\left|\frac{V_n(k,c,z)-V_{n-1}(k,c,z)}{V_{n-1}(k,c,z)}\right| < 0.00001$, where n is the iteration number.[4]

We solve the entrant problem by value function iteration. We discretize the signal space using 100 grid points over the interval $[\underline{q}, +\infty]$ and draw entrants from this interval using a discrete version of the Pareto distribution with lower bound $\underline{q}$ and shape parameter ξ.

C.2. SMM

We use simulated method of moments to estimate the eight parameters: the returns-to-scale parameter α, the convex adjustment cost parameter η, the persistence of the TFPR process ρ and its volatility σ, the cost of accumulating cash ν, the fixed equity issuance cost f_e govern, the lower bound $\underline{q}$, and the shape parameter ξ of the Pareto distribution. The estimation follows the steps below:

- For a given parameter vector $\theta = \{\alpha, \eta, \rho, \sigma, \nu, f_e, \underline{q}, \xi\}$ of dimension P, we use the optimal investment and financing policies for incumbents and entrants to simulate K times a balanced panel of N firms of length ten years. N is the actual the number of firms in each of the various cohorts, while K is set equal to 50. We keep the set of exogenous shocks the same across the K simulations to avoid simulation noise.
- For each set of parameters, we use the simulated data $y_{i,k}(\theta)$ to calculate a set of M=13 simulated moments $h(y_{i,k}(\theta))$ that are useful in identifying our structural parameters. The set of simulated moments is the artificial analogous of the set of data moments $h(x_i)$, where x_i is a data vector of dimension N.
- The simulated method of moments estimator $\hat{\theta}$ is the solution to the following minimization problem:

$$\hat{\theta} \quad = \quad arg\min_{\theta} Q(\theta, n) \equiv g(x, \theta)'\hat{W}g(x, \theta), \tag{C.1}$$

  where $g(x, \theta)$ is a sample moment vector of dimension $M \times 1$ such that

$$g(x_{it}, \theta) = \frac{1}{N}\sum_{i=1}^{N}\left[h(x_i) - \frac{1}{K}\sum_{k=1}^{K} y_{i,k}(\theta)\right], \tag{C.2}$$

  and $\hat{W}$ is a positive definite $M \times P$ weighting matrix that converges in probability to a deterministic positive definite matrix W. We use a standard simulating annealing technique to find $\hat{\theta}$. [5]
- We calculate the weighting matrix $\hat{W}$ using the influence function approach in Erickson and Whited (2002). Specifically, we calculate the influence function for each of the M moments, and then we covary the influence functions (summing over $i = 1, ..., N$) to obtain an estimate of $h(x_i)$'s variance-covariance matrix $\hat{\Omega}$. In the minimization problem, we set $\hat{W}$ equal to the diagonal of the inverse of the variance-covariance matrix $\hat{\Omega}$. In this way, we put least weight on the moments that are estimated with the least precision.[6]
- After finding $\hat{\theta}$, we derive its standard errors using its asymptotic distribution:

$$avar(\hat{\theta}) \quad = \quad \left(1 + \frac{1}{K}\right)[GWG']^{-1}[GW\Omega WG'][GWG']^{-1}, \tag{C.3}$$

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[4]Note that the optimal cash policy c' can be outside the grid used to approximate the corresponding state for the value function. When we simulate the model, we randomly assign an optimal cash policy c' to a grid point for cash using the following probabilities: with probability $1 - \frac{c'-c_{i-1}}{c_{i-1}}$, the assigned gridpoint is c_{i-1}, while with probability $\frac{c'-c_{i-1}}{c_{i-1}}$, the assigned gridpoint is c_i. c_{i-1} and c_i are two consecutive gridpoints such that $c' \in [c_{i-1}; c_i]$.

[5]We use the Fortran 90 version prepared by Alan Miller; the code can be downloaded at https://jblevins.org/mirror/amiller/simann.f90

[6]See Bazdresch, Kahn, and Whited (2018) for a discussion and comparison of the finite sample properties of different weighting matrix choices.

where $G \equiv \partial g(x_{it}, \theta)/\partial\theta$. We calculate the numerical derivative using a five-point stencil:

$$\partial g(x_{it}, \theta)/\partial\theta \approx \frac{-g(x_{it}, \theta + 2\varepsilon) + 8g(x_{it}, \theta + \varepsilon) - 8g(x_{it}, \theta - \varepsilon) + g(x_{it}, \theta - 2\varepsilon)}{12\varepsilon}. \tag{C.4}$$

Note that W is not the diagonal of the inverse of the variance-covariance matrix $\hat{\Omega}$. Instead we set W equal to the inverse of $\hat{\Omega}$.

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