NBER WORKING PAPER SERIES

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Working Paper 23249
http://www.nber.org/papers/w23249

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
March 2017

We are particularly grateful to Joan Farre-Mensa for comments and suggestions and Young Min Kim for excellent research assistance. We are also grateful to Rajesh Aggarwal, Rui Albuquerque, Andrea Buffa, Gian Luca Clementi, Marco Da Rin, Fritz Foley, Ambrus Kecskés, Pablo Kurlat, Evgeny Lyandres, Sébastien Michenaud, Stefano Sacchetto, Martin Schmalz, Ken Singleton, Viktoriya Staneva, Anna-Leigh Stone, and Toni Whited 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, and Driehaus College of Business for their comments and suggestions. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

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NBER Working Paper No. 23249
March 2017
JEL No. E3,G1,G3

ABSTRACT

Among stock market entrants, more firms over time are R&D–intensive with initially lower profitability but higher growth potential. This sample-selection effect determines the secular trend in U.S. public firms' cash holdings. A stylized firm industry model allows us to analyze two competing changes to the selection mechanism: a change in industry composition and a shift toward less profitable R&D–firms. The latter is key to generating higher cash ratios at IPO, necessary for the secular increase, whereas the former mechanism amplifies this effect. The data confirm the prominent role played by selection, and corroborate the model's predictions.

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1 Introduction

The *average* U.S. public firm has changed its characteristics over the last 35 years. The disappearance of dividends (Fama and French (2001)), the decline in profitability (Fama and French (2004)), the increase in cash holdings (Bates et al. (2009)) and firm-specific risk measures (Davis et al. (2007) and Brown and Kapadia (2007)) are phenomena of this period. A change in the behavior of the average public firm could be caused by a change in the behavior of incumbent firms as well as by the selection of a different type of firm into the stock market that gradually replaces incumbent firms over time.

This paper studies and quantifies the role of sample selection for the secular increase in the average cash–to–assets ratio of U.S. public companies over the last 35 years.[1] The following facts motivate our research. Since the beginning of the 1980s, firms went public with progressively higher cash–to–assets ratios, but they reduced their cash ratios gradually afterward (see Figure 1).[2] This feature of the data is indicative of a sample-selection mechanism, namely, a change in the conditions that determine which firms choose to enter the stock market. Figure 2 shows that at least two features of entering cohorts have changed over time, pointing to two different selection mechanisms. First, the share of R&D–intensive firms in U.S. public markets has increased substantially due to a growing fraction of R&D–intensive newly listed firms (left panel). Second, R&D–intensive firms have entered with progressively higher cash balances (right panel), suggesting a change in the type of R&D–intensive stock market entrants.

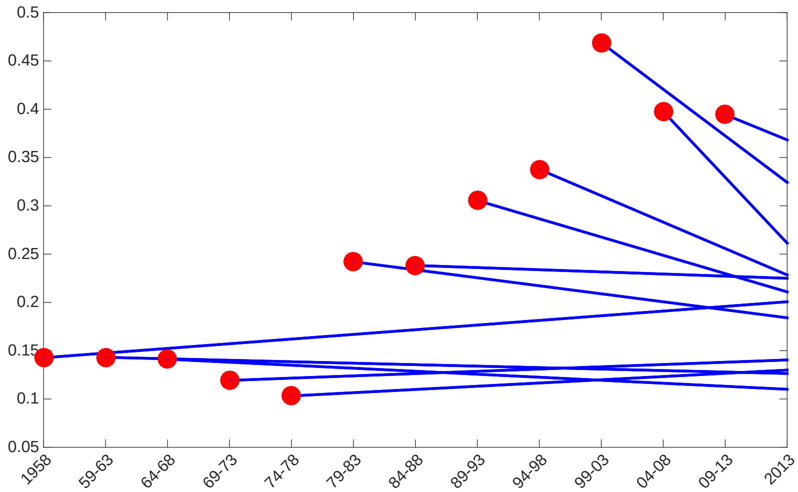
The compositional change of U.S. public companies corresponds to a shift in the composition of the overall U.S. economy toward R&D–intensive firms.[3] For example, Haltiwanger, Hathaway, and Miranda (2014) document a significant increase in the number of

[1]We report the evolution of the average cash–to–assets ratio of U.S. listed firms during the period 1958–2014 in Appendix B.

[2]Figure 1 presents the cash–to–assets ratio dynamics at the cohort level starting with the 1959-1963 cohort. The red dot marks the average cash holdings at entry for each cohort. The straight blue line links the initial average cash holdings upon entry to the average cash holdings of the cohort in 2013. A negative (positive) slope means the average cash holdings at the cohort level decline (increase). The first observation is the average cash–to–assets ratio of incumbent firms in 1958.

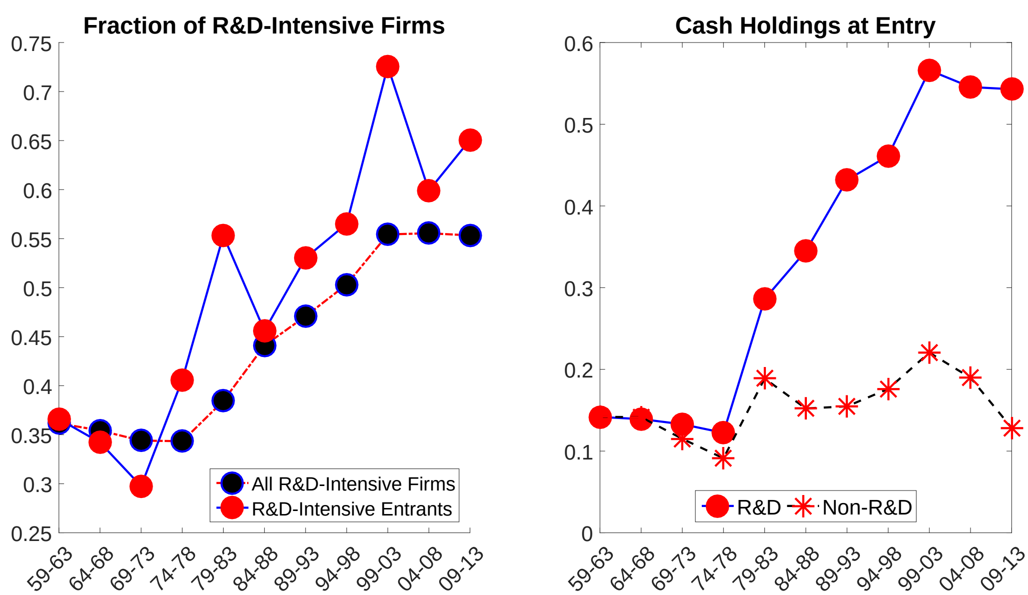
[3]This fact has been widely documented by the literature on the structural change of the U.S. economy after World War II (e.g. Buera and Kaboski (2012) and references therein).

Figure 1: Average Cash Holdings at Entry (1959-2013)



The figure reports the evolution of the cash–to–assets ratio for U.S. public companies for 11 5-year cohorts over the period 1959-2013. The red dot denotes the average cash ratio at entry for each cohort. The first observation denotes the average cash holdings of incumbent firms in 1958. The straight line connects the initial average cash holdings to the average holding in 2013 for each cohort.

Figure 2: Industry Composition of U.S. Public Firms (1959-2013)



The left panel of this figure presents the share of R&D–intensive firms in Compustat (in darker color with a dashed line) and the share of R&D–intensive entrants (in red with a solid line). The right panel shows the average cash–to–assets ratio at entry of R&D–intensive and non–R&D–intensive firms. A R&D–intensive firm belongs to an industry (three-level digit *SIC* code) whose average R&D investment amounts to at least 2% of assets over the sample period. We group firms into cohorts of five years starting from 1959. We define as *entrant* a firms that reports a fiscal year-end value of the stock price for the first time (item $PRCC\_F$).

high-tech startups during the period 1982–2007 relative to other startups. A larger ratio of R&D–intensive to non R&D–intensive firms in the economy increases the likelihood of an IPO by R&D–intensive firms, all else being equal.

The increase in cash holdings of newly listed R&D–intensive firms suggests each new cohort to the stock market has different characteristics. Indeed, over time newly listed firms are smaller, less profitable, and appear to exhibit higher cash-flow volatility compared to previous cohorts. In the spirit of Fama and French (2004), the selection of a different type of firm could be driven by more favorable IPO conditions that have allowed *weaker* firms to go public (i.e., *"a downward shift in the supply curve for new list equity funding"* Fama and French (2004, page 233)). Such a change could have been instigated by the relaxation of the Employment Retirement Income Security Act's (ERISA) "Prudent Man" Rule passed by Congress in 1979 that induced pension funds to invest in riskier (i.e., smaller, less profitable, and higher growth option) ventures.[4] The ensuing improvement in IPO conditions for risky firms might have particularly benefited R&D–intensive firms, as indicated by Figure 2.

In the first part of this paper, we build a stylized firm industry model with endogenous entry to gain insights into how these two selection mechanisms can shape the secular increase in cash holdings. The benefit of a model is that we can isolate confounding effects and develop testable predictions. In the second part of the paper, we test whether the data corroborate the model's predictions.

Our firm industry model assumes firms belong to two sectors that share the same production technology and financing opportunities. We interpret old-economy firms as non-R&D–intensive and new-economy firms as R&D–intensive. Guided by the evidence in Figure 2, we assume that only firms in the new-economy sector experience an improvement in

[4]As noted in Longstreth (1987, page 101) *"The Venture Capital and Innovation Study prepared in 1984 for the Joint Economic Committee of the Congress reports that 63.5 percent of the venture capital firms consulted believed there was a bias among institutional investors against investing in small businesses, with the leading causes being a lack of institutional expertise in small business investing and the "excessive risk-adverse behavior of institutional investors." While perhaps itself biased, this view lends some support to the idea that the prudent man rule exerts a restraining influence. More telling was the study's findings (a) that the liberalizing regulations issued by the Labor Department in June 1979 were a "major factor" in the surge of pension fund investment in venture capital after that date, and (b) that the uncertainties of the federal prudent man rule contained in ERISA, including the possibility of being judged investment-by-investment, may have contributed to a shift toward greater risk aversion by pension fund fiduciaries from 1974, when ERISA was enacted, until the interpretative regulations of 1979."*

the conditions that influence their entry decisions. A reduction in entry costs causes firms with lower idiosyncratic productivity (i.e., less profitable firms with high growth potential) to go public. The assumed mean reversion in the productivity process implies these firms have higher funding needs and choose higher cash balances at entry to save up for future investment opportunities in order to avoid equity issuance costs. As these firms grow, they reduce their cash holdings given that they can rely more on internal funds, thus making the model consistent with the evidence in Figure 1.

The model predicts that the first selection mechanism, a change in the industry composition at entry (*across-industry* selection), plays no role in shaping the secular increase in cash. However, it provides an important amplification mechanism when coupled with the entry of less-profitable, high-growth-potential new-economy firms (*intra-industry* selection). This second selection effect is necessary to generate increasing cash holdings at entry over time that, in turn, lead to a steady increase in the average cash–to–assets ratio in the cross section. In addition, the model suggests the turnover ratio plays a major role in determining the cash holdings of entering firms given its tight connection with firm-level profitability since the ratio of sales over total assets is proportional to profitability in the model.

In the second part of the paper, we measure the importance of sample selection in determining the secular increase in cash, and test the model's predictions in the data. We first show that sample selection is a major cause for the secular increase in cash holdings. Our evidence is straightforward. On average, firms deplete their cash holdings over time, as measured by a negative time trend within firms. Yet, on average, firms' cash holdings have increased. Thus, the increase in cash holdings is a consequence of newly listed firms increasing their cash holdings at entry faster than the rate at which incumbents deplete theirs. Using a simple accounting identity, we decompose the change in the average cash-to-assets ratio over the period 1979–2013 (0.151) in the contribution due to the entry margin (sample-selection effect) and the contribution due to incumbent firms (within effect). We show that sample selection accounts for more than 200% of the secular increase in cash holdings (0.329), whereas the contribution of the within change is actually -117% (-0.178).

Next, we present evidence for the two selection mechanisms our model highlights. To this end, we construct random subsamples from the data that control for both selection effects so that (1) R&D–intensive entrants in the stock market have an average cash–to–assets ratio as in 1974-1978 (pre-secular increase), and (2) the proportion of R&D–intensive entrants is the same as in 1974-1978. When both restrictions are imposed, we can hardly generate a positive trend in average cash holdings. At the same time, R&D–intensive entrants are relatively larger and more efficient (i.e., higher turnover ratio) compared to the data, as predicted by the model. Allowing for an *across-industry* selection mechanism by lifting restriction (2) results in a small increase in average cash holdings that is not large enough to fit the data. Moreover, R&D–intensive entrants are larger and exhibit higher turnover ratios compared to the actual sample. Lifting only restriction (1), that is, allowing for an *intra-industry* selection, results in R&D–intensive entrants whose evolution of characteristics in terms of size and turnover ratios are in line with the data. As predicted by the model, average cash holdings increase, but not by as much as to match the data. For this to happen, we need to lift both restrictions so that the *across-industry* selection mechanism amplifies the effects of the *intra-industry* selection mechanism.

In our model, the turnover ratio is proportional to firm-level productivity and, as such, is an important determinant for cash holdings at entry. We conclude the empirical analysis by assessing the explanatory power of the latter variable. We find the turnover ratio is indeed an important predictor of cash holdings at entry, and its dominant explanatory power is not subdued when we include a set of important determinants of corporate cash holdings that have been discussed in the literature.

Our paper contributes to the debate on the causes of the increase in cash holdings among U.S. publicly listed firms.[5] A rich literature uses heterogeneous dynamic corpo-

[5] The literature on the determinants of cash holdings is extensive and ranges over many decades. A classic motive for holding cash is transaction costs (e.g., Baumol (1952), Tobin (1956), Miller and Orr (1966), and Vogel and Maddala (1967)). Other motives include taxes (e.g., Foley, Hartzell, Titman, and Twite (2007)), precautionary savings (e.g., Froot, Scharfstein, and Stein (1993), Kim et al. (1998)), and agency costs (e.g., Jensen (1986), Dittmar and Mahrt-Smith (2007) and Nikolov and Whited (2014)). Opler et al. (1999) provide an extensive test of these different motives. In the last decade, the secular increase in cash holdings has received much attention and spurred many explanations that are not based on sample selection, for example, a tax-based explanation by Foley, Hartzell, Titman, and Twite (2007) and Faulkender and Petersen (2012), a precautionary savings motive by Bates, Kahle, and Stulz (2009), McLean (2011), and Zhao (2015), operative changes by Falato, Kadyrzhanova, and Sim (2013) and Gao (2015), as well as the cost of carrying cash (e.g. Azar, Kagy, and Schmalz (2016) and Curtis, Garin, and Mehkari (2015)).

rate finance models to understand and quantify corporate cash policies (e.g., Gamba and Triantis (2008), Riddick and Whited (2009), Anderson and Carverhill (2012), and Nikolov and Whited (2014)) as well as the secular increase in cash holdings (e.g., Falato et al. (2013), Gao (2015), Zhao (2015), Armenter and Hnatkovska (2016), Chen et al. (2017)). The firm's optimization problem in our model is based on Riddick and Whited (2009). To the best of our knowledge, our stylized model provides one of the first dynamic corporate finance models that explicitly allows for the presence of various selection mechanisms and is qualitatively consistent with the stylized facts we document in Figures 1 and 2.

Heckman (1979) highlighted how ignoring sample selection can lead to biased estimates. In our model, the standard decreasing returns-to-scale assumption in combination with the entry of less profitable firms over time is sufficient to generate higher cash–to–assets ratios and higher sales-growth volatility. Empirical estimates that do not control for sample selection may incorrectly infer that the underlying cash–flow process has become more volatile. Put differently, those estimates could assign too much importance to increased uncertainty when in fact selection contributed to the rise in measured cash-flow volatility and cash holdings.[6]

In this paper, we argue that selection is a key driver for the secular increase in the cash-to-assets ratio. We are not the first to point out that newly listed firms in R&D–intensive industries appear to play a role.[7] Bates, Kahle, and Stulz (2009) find that high–tech, non-dividend payers and recently listed firms have successively higher cash ratios, but they also find an increase in the non-high–tech sectors.[8] Booth and Zhou (2013) present evidence that the increase in the average cash–to–assets ratio is due to changing firm characteristics of high-tech firms that went public after 1980. In concurrent work, Graham and Leary (2016) study the determinants of cash policies using data from the 1920s onward to investigate what factors were most important for cash holdings over different periods. Related to the period we study, they also find that average cash holdings began to rise in about 1980 even

[6]Roberts and Whited (2013) provide a survey of potential endogeneity issues in empirical corporate finance.

[7]Several papers find a positive relationship between cash and R&D expenditures (e.g., Opler and Titman (1994), Opler, Pinkowitz, Stulz, and Williamson (1999), Brown and Petersen (2011), Falato and Sim (2014), He and Wintoki (2014), Lyandres and Palazzo (2015), and Malamud and Zucchi (2016) among many others).

[8]We discuss this difference in section 3.2 and 3.3.

though within-firm cash balances declined over this period. They also attribute the post-1980 rise in average cash balances to changes in sample composition due to new health and tech NASDAQ firms going public with large cash balances.[9]

We expand on these insights by (1) proposing an empirical measure of the selection effect, (2) providing evidence for the two sample-selection mechanisms advanced by the model, and (3) highlighting the importance of the turnover ratio (sales over assets) as an important determinant of cash holdings at entry and therefore the secular increase in cash holdings.

The paper is organized as follows. We present the model in Section 2. The results of the empirical analysis are in Section 3. We first empirically assess the contribution of sample selection to the secular increase in cash holdings. Then, in Section 3.4, we explicitly study the impact of different selection mechanisms. We conclude in Section 3.5 by comparing the explanatory power of the turnover ratio with other important determinants of corporate cash holdings.

2 Selection and average cash holdings: insights from a firm industry model

In this section, we develop a stylized heterogeneous firm industry model to illustrate how changes in the selection process can be a major driver of the average cash-to-assets ratio over time. We assume firms belong to one of two sectors labeled as the new-economy sector and old-economy sector. We set up the firm problem similarly to Riddick and Whited (2009). That is, firms use a decreasing returns-to-scale technology with capital as the only input. Firms can finance themselves with equity or with internal funds. We assume a time-invariant mass of potential firms exists that endogenously decides to become public (i.e., entry in the stock market). These potential entrants are either new-economy or old-economy firms.

To highlight the effect of the entry margin, both firm types are modeled identically. That is, we assume firms in both sectors share the same production technology and have the same

[9] Seventy percent of the R&D–intensive entrants in our sample are listed on NASDAQ, while 20% are listed on the NYSE, and the remainder on AMEX.

financing opportunities. The only difference between these sectors is that, contrary to old-economy firms, new-economy firms experience a change in the conditions that influence their entry decision.

2.1 Incumbent problem

This section presents the incumbent problem that is identical across both sectors.

Technology Firms produce using the decreasing returns-to-scale production function $y_t = e^{z_{t+1}k_t^\alpha}$, where z_{t+1} is an idiosyncratic productivity shock that evolves according to

$$z_{t+1} = \rho z_t + \sigma\epsilon_{t+1}, \qquad \epsilon_{t+1} \overset{i.i.d.}{\sim} N(0,1).$$

The law of motion for the capital stock is $k_{t+1} = (1-\delta)k_t + x_t$, where δ is the depreciation rate and x_t is the capital investment at time t that entails an adjustment cost equal to

$$\phi(k_{t+1}, k_t) = \eta\left(\frac{k_{t+1} - (1-\delta)k_t}{k_t}\right)^2 k_t.$$

Financing Firms can finance their operations internally by transferring cash from one period to the next at an accumulation rate $\widehat{R}$ lower than the (gross) risk-free rate R. In particular, we assume $\widehat{R} = \nu R$, where $\nu \in (0,1)$. Firms can also raise external resources by issuing equity. Equity financing is costly: raising equity (i.e., having a negative dividend $d_t < 0$) requires the payment of $H(d_t)$, where $H(d_t) = -\kappa|d_t|$.

Incumbent's problem Let $V_t = V(k_t, c_{t,} z_t)$ be the value of the firm, and then the time t value of an incumbent firm solves the functional equation below:

$$V_t \equiv \max_{c_{t+1}\geq 0, x_{t+1}} d_t + H(d_t)\,\mathbf{1}_{[d_t\leq 0]} + \frac{1-\lambda}{R}E_t\left[V_{t+1}\right] + \frac{\lambda}{R}E_t\left[w_{t+1} + (1-\delta)k_{t+1}\right], \qquad (1)$$

subject to

$$
\begin{aligned}
d_t &= w_t - \frac{c_{t+1}}{\widehat{R}} - x_{t+1} - \phi(k_{t+1}, k_t), &(2)\\
k_{t+1} &= (1-\delta_j)k_t + x_{t+1}, &(3)\\
w_{t+1} &= e^{z_{t+1}} k_{t+1}^{\alpha} + c_{t+1}. &(4)
\end{aligned}
$$

Equation 2 is the firm's budget constraint. The firm can use the total resources available to distribute dividends (d_t), invest in capital (x_{t+1}), and pay the adjustment cost ($\phi(k_{t+1}, k_t)$), or to accumulate cash internally $\left(c_{t+1}/\widehat{R}\right)$. If the initial net worth w_t is not enough to cover for the investment and financing needs, the firm issues equity (i.e., d_t is negative) and pays an equity issuance cost equal to κd_t. In what follows, $\mathbf{1}_{[d_t \leq 0]}$ is an indicator function that takes the value of 1 only if the firm needs to issue equity at time t. Choosing cash holdings (c_{t+1}) and investment (x_{t+1}) determines the next-period net worth (w_{t+1}). Each period, the firm faces an exogenous exit probability, λ.[10] Upon exit, the firm recovers its net worth and depreciated capital stock.

2.2 Entry

Every period, a constant mass $M > 0$ of firms has the option to go public (potential entrants in the stock market). M is the sum of $M_n > 0$, the mass of new-economy firms that are private, and $M_o > 0$, the mass of old-economy firms that are private. We define ω as the fraction M_o/M.

Following Clementi and Palazzo (2016), we introduce heterogeneity in firms that go public, by assuming each potential entrant in the stock market receives a signal q about its future productivity. This signal follows a Pareto distribution $q \sim Q(q)$ whose shape is governed by the parameter ξ. Conditional on entry, the distribution of the idiosyncratic shocks in the first period of operation is $z_{t+1} = \rho q_t + \sigma \epsilon_{t+1}$. Firms decide to go public if

[10] This assumption is innocuous in the context of our exercise. Figure 12 in the appendix shows the average cash holdings for exiting firms is very close to the average cash holdings of incumbent firms. This feature of the data can be replicated by an i.i.d. exit process. In the data as well as in the model, we allow exit to be defined in a broader sense that includes firms disappearing from the data or the model due to acquisitions and mergers, bankruptcy, or going private.

the value of being a publicly traded firm exceeds the value of staying private V_p. The value function for a potential entrant is

$$V^E(q_t) = \max_{c_{t+1}, x_{t+1}} \left\{ -x_{t+1} - \frac{c_{t+1}}{\hat{R}} + \frac{1}{R} E[V(k_{t+1}, c_{t+1}, z_{t+1})|q_t] \right\}. \quad (5)$$

A firm goes public if and only if $V^E \geq V_p$.[11]

2.3 The underlying mechanism: mean reversion in productivity

This section describes the tight link between the cash–to–assets ratio of entrants and their productivity state. Before we go into more detail on this link, we first briefly sketch out the model parametrization. The firm industry equilibrium and the solution method are described in the appendix (Section A.1). We parametrize the model at an annual frequency using calibrated values that match key features of U.S. public firms. The calibration strategy is laid out in detail in Section A.2. To highlight the role of selection, we calibrate the parameters listed in Table 1 using the period 1959-1979, that is, before a marked increase in the cash–to-assets ratio. Panel A lists standard parameters that we borrowed from the literature. Panel B reports the calibrated parameters, their value, the targeted data moment, and the equivalent model moments. Finally, Panel C reports the calibration target for the exit-rate parameter λ that has been chosen to map the age distribution in the model as close as possible to the age distribution in the data.

The policy functions (Section A.3) are fairly standard. The key insights from those policy functions is the importance of precautionary financing for small firms. Large firms have a smaller precautionary savings motive because they rely on larger expected cash flows, and for this reason, they need to retain less cash when financing constraints are binding. Conversely, small firms engage in larger precautionary savings, and in doing, so they deliver a larger cash-to-assets ratio.

This paper stresses the importance of the entry margin, i.e. the selection process. The

[11] We follow a reduced-form approach to model the going-public decision and choose not to model the problem of the private firm. The selection mechanisms that drive our results will also operate in a more realistic setup along the lines of Clementi (2002).

Table 1: PARAMETRIZATION

Panel A: Parameters from other studies

Parameter	Function in Model	Origin/Target
$\alpha = 0.62$	Decreasing returns to scale	Hennessy and Whited (2007)
$\delta = 0.15$	Depreciation rate	Hennessy and Whited (2007)
$r = 0.04$	Riskless rate	Riddick and Whited (2009)
$\sigma = 0.121$	Volatility firm-level shock	Riddick and Whited (2009)

Panel B: Calibrated parameters

Parameter	Function in Model	Moment Target	Data	Model
$\omega = 0.668$	Firms' composition	Proportion of new firms	0.332	0.332
$\rho = 0.90$	Productivity persistence	Sales growth rate volatility	0.177	0.162
$\nu = 0.995$	Cost of carrying cash	Average cash	0.082	0.093
$V_p = 0.0141$	Value of staying private	Average cash at entry	0.142	0.144
$\kappa = 0.14$	Equity issuance costs	Average equity-to-asset ratio	0.053	0.053
$\eta = 0.015$	Adjustment cost	Investment rate volatility	0.208	0.187
$\xi = 15$	Pareto distribution	Relative size entrant	0.663	0.697

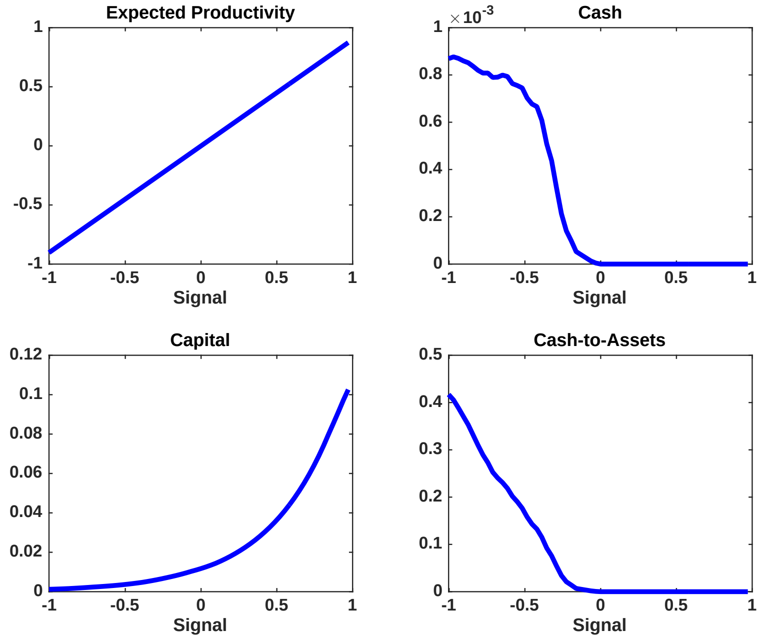
Panel C: Age distribution with exit rate $\lambda = 0.07$

Age Bins	1-5	6-10	11-15	16-20	>20
Model	0.302	0.211	0.147	0.102	0.238
Data	0.296	0.206	0.159	0.119	0.221

The table presents the parametrization of the model. In panel A and B, the parameter values are listed in the first column, the function in the model are described in the second column, and the targets are listed in the third column. Panel A presents the parameters we set to values from the literature. Panel B presents the parameters we calibrate to moments in the data. Panel C presents the age distribution implied by the model using an exit rate of $\lambda = 7\%$ and compares it to the data. A detailed description of the parametrization strategy is in appendix section A.2.

policy functions for entrants in Figure 3 are therefore particularly interesting. Importantly for the mechanism, they show a tight link between entrants' cash–to–assets ratio and expected productivity. The higher the signal q, the higher the expected productivity ρq conditional on observing q (see the top left panel) and cash flow in the immediate future. As the signal improves, firms decide to invest more (bottom left panel). When the signal is below average, mean reversion in the productivity process implies firms can expect to reach a higher productivity state in the long run. Thus, they forecast higher investment needs going forward. For this reason, firms with low q choose to save some of the IPO proceeds as cash to

Figure 3: Policy Functions at Entry



The figure reports the characteristics at entry for a firm as a function of the entry signal. The top left panel depicts the expected firm-level productivity, the bottom left panel the capital choice at entry, the top right panel the cash balance, and the bottom right panel the cash balance divided by total assets (i.e., capital plus cash holdings).

invest later (top right panel) in order to minimize future equity issuance cost. If the signal is sufficiently good, the firm decides not to save any cash. The bottom right panel reports the cash–to–assets ratio of an entering firm. As the signal improves, the firm saves less cash and invests more, thus generating a decrease in the cash–to–assets ratio. In sum, these policy functions highlight the importance of entrants' productivity for the average cash–to–assets ratio. Less profitable firms with low current productivity expect high growth and therefore have a higher demand for investment in the long run. To avoid tapping into costly external financing sources too frequently, they choose to save in cash.

2.4 Changes in the selection process and average cash holdings

Armed with the model, we investigate how the two selection mechanisms (i.e., selecting relatively more new–economy firms versus selecting initially less profitable new–economy firms) shape the average cash holdings' dynamics. The starting point is the steady state of the benchmark model calibrated to data from the 1959-1979 period, where the economy is populated by identical firms.

The first experiment is designed to explore the effect of a structural change in the composition of firms (across-industry selection mechanism) on the average cash-to-assets ratio (top left panel of Figure 4). To this end, we assume the fraction of potential entrants of type old ω changes over a time span of 35 years so that the model replicates the compositional change for publicly traded firms in the data (top right panel of Figure 4).[12]

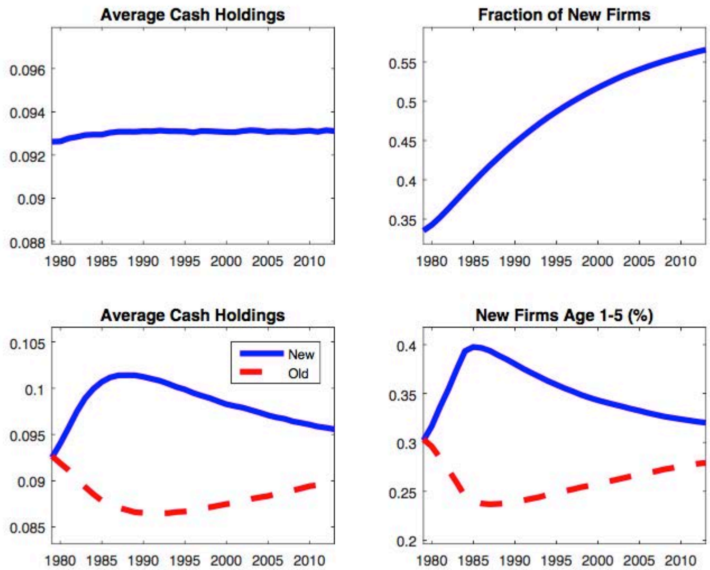
A structural change in the composition of entrants is unable to generate a secular increase in the average cash holdings of publicly traded firms. The solid blue lines in the bottom panels of Figure 4 show the increase in average cash holdings for new-economy firms (bottom left panel) is due to the increase in the proportion of young firms (bottom right panel). Given that exit is i.i.d., a progressively larger fraction of new-economy entrants leads to an increase in the proportion of young new-economy firms. These firms are smaller and have, on average, larger cash-to-assets ratios relative to their more mature counterparts.

This positive effect on average cash holdings is counterbalanced by the dynamics of cash holdings for old-economy firms, as illustrated by the dashed red lines in the bottom panels of Figure 4. Because old economy firms enter in a smaller number, their composition shifts toward more mature firms that have, on average, lower cash-to-assets ratios. This effects leads to an initial decrease of average cash holdings. It follows that the cash-holdings dynamics in the two sectors offset each other, thus leaving the overall cash-to-assets ratio unchanged over time, as described by the top left panel of Figure 4. Without a change in the characteristics at entry of new-economy firms, the model cannot generate an increase in average cash holdings.

Our second experiment investigates how a change in the characteristics of new-economy entrants (*intra-industry* selection) affects the cash–to–assets ratio. Motivated by the changes to institutional investors' investment opportunities at the end of the 1970s discussed in the

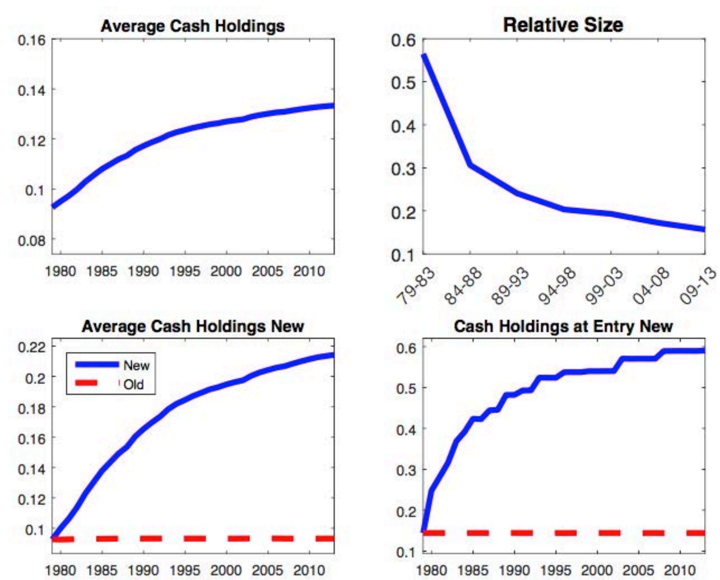
[12] To be precise, we assume the fraction of potential entrants of type old evolves over time according to $\omega_t = (\omega - a_1) + a_1 t^{-a_2}$, where $t = 1, ..., 35$. We pick a_1 and a_2 to minimize the distance between the compositional change generated by the model and the one observed in the data. The calibrated values of a_1 and a_2 deliver a fraction of potential entrants of type old equal to 40% after 35 years.

Figure 4: Increase in share of new-economy firms



This figure reports the effect of an increase in the share of new-economy firms on average cash holdings. The top left (right) panel reports the evolution of average cash holdings (the fraction of new firms) over 35 years. The bottom left panel reports the average cash holdings of new-economy and old-economy firms. The bottom right panel reports firms that have gone public in the last five years (young firms) as a fraction of the total number of firms. This quantity is calculated separately for the two sectors.

Figure 5: Reduction in entry costs for new-economy firms



This figure reports the effect of a decrease in the entry cost for new-economy firms on average cash holdings.

introduction, we study the response of the model to a reduction in the value of staying private for new-economy firms. We assume a reduction in V_p over 35 years to mimic the dynamics of the relative size of entering firms.[13] Figure 5 shows this change reduces the threshold productivity level for entry. That is, even small (top right panel) and less productive firms (i.e., low-profitability firms with higher growth potential) choose to go public. Because the shocks are mean reverting, lower-productivity firms anticipate higher productivity in the future and raise more cash relative to their assets at the IPO stage (bottom right panel). This behavior is a natural consequence of the entrants' policy function discussed in section 2.3. This selection mechanism only affects the average cash-to-assets ratio of new-economy firms (bottom left panel), thus replicating the empirical evidence in Figure 2 of R&D–intensive firms entering with progressively higher cash balances. The model can explain around 26% of the total change in cash holdings.[14]

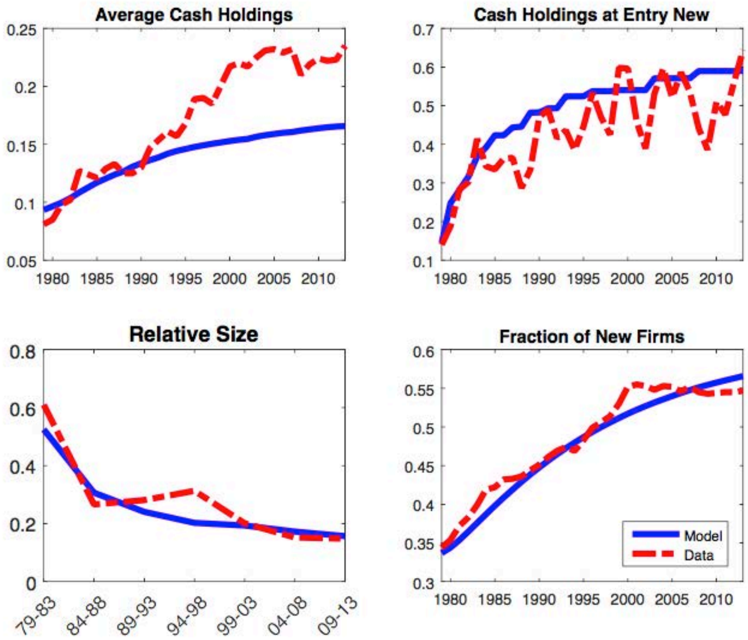
On its own, neither selection mechanism is quantitatively strong enough to explain the secular trend in cash holdings. However, the combination of the *intra-industry* selection effect with the *across-industry* selection effect - a purely selection-based mechanism - explains 46% of the trend.

Figure 6 compares the data (dashed red lines) with the data generated by a model that considers both selection mechanisms (solid blue lines). Adding a change in composition on top of a reduction in the value of staying private for new-economy firms helps the model along two dimensions. The model generates both a secular increase in cash holdings for new economy firms at entry (top right panel) and a shift in the composition toward new-economy firms (bottom right panel). The latter *across-industry* selection mechanism increases the number of new economy entrants that are smaller in the cross section, thus amplifying their effect on the average cash-to-assets ratio. This amplification channel leads to a steeper

[13] We calculate the relative size using median values of size at entry for the seven cohorts during the period 1979-2013. We measure size in 2009 dollars using total sales (Compustat Item SALE). We assume the value of staying private for entrants of type new evolves over time according to $V_{p,n,t} = (V_{p,n} - a_1) + a_1 t^{-a_2}$, where $t = 1, ..., 35$. We pick a_1 and a_2 to minimize the distance between the relative size at entry generated by the model and the one observed in the data.

[14] The increase in the average cash-to-assets ratio for new-economy firms leads to an overall increase from a steady-state value of 0.093 to a value of 0.133 (top left panel). In the data, the average cash-to-assets ratio increases from a value of 0.081 in 1979 to a value of 0.235 in 2013. Thus, the model explains around 26% of the total change in cash holdings documented in the data (i.e., (0.133-0.093)/(0.235-0.081)).

Figure 6: Combined

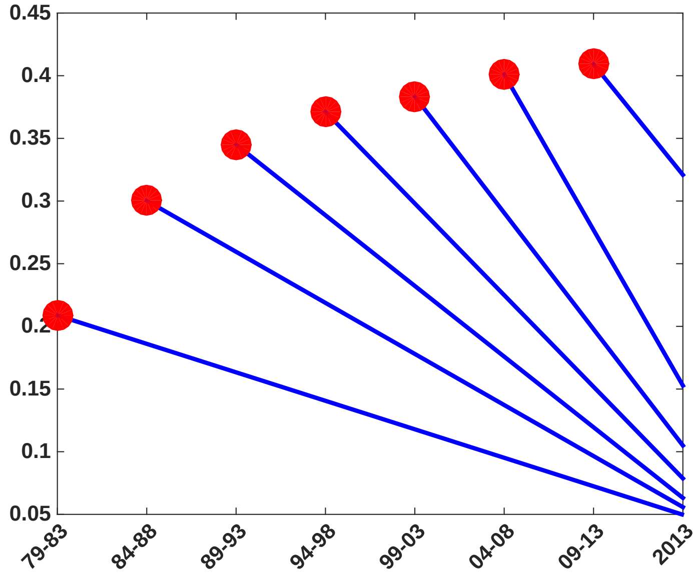


This figure reports the effect of a reduction in the value of staying private for new-economy entrants and an increase in the share of new-economy firms in the economy. The solid blue line depicts the simulated data and the dashed red line depicts the empirical counterpart.

secular increase in average cash holdings that brings the model closer to the data. Over 35 years, average cash holdings go from a steady state value of 0.093 to a value of 0.166, a 78% increase (top left panel). This purely selection-based model generates 46% (i.e., (0.166-0.093)/(0.235-0.081)) of the increase in average cash holdings in the period between 1979 and 2013.

As in the data (see Figure 1), our model captures the mean-reverting nature of the cash-to-assets ratio and thus generates the secular increase purely with the two selection mechanisms as shown in Figure 7, which is the model counterpart of Figure 1. This stylized model provides useful guidance on how to approach the question of why the average cash–to–assets ratio has increased. In the next subsection, we discuss additional implications of sample selection that go beyond the secular increase in cash holdings.

Figure 7: Model-Generated Average Cash Holdings at Entry (1979-2013)



The figure reports the evolution of the cash–to–assets ratio for model-generated firms using seven five-year cohorts over the period 1979-2013. The red dot denotes the average cash holdings at entry for each cohort. The straight line connects the initial average cash holdings to the average holding in 2013 for each cohort.

2.5 Additional model's implications

In addition to being consistent with firms' cash-holding dynamics, our stylized model is also qualitatively consistent with a number of other documented trends in U.S. public firms over the last 35 years. In Table 2, we summarize the additional predictions of the model. As discussed above (section 2.4), we target the size of new-economy firms relative to old-economy firms at entry to discipline the reduction in V^P (outside option). The model counterpart of the relative size at entry is shown in column I of Table 2.

First, the model predicts new-economy entrants have not only become relatively smaller (column I), but also require a progressively lower profitability signal to enter the equity market. A lower signal leads to a decline in the average firm-level productivity (shock) at entry relative to old-economy firms, as shown in column II of Table 2. Due to the decreasing returns-to-scale assumption, the reduction in the relative size of new-economy entrants decreases the relative turnover ratio (i.e., the sales-to-assets ratio), as shown in column III. The latter value goes from 83% for the cohort 1979-1983 to 47% for the cohort

Table 2: Additional Implications of Sample Selection

	Rel. size at entry	Rel. productivity at entry	Rel. turnover at entry	Cash-to-asset	Sales' volatility	Rel. sales' volatility
	I	II	III	IV	V	VI
1979-1983	0.524	-0.222	0.834	0.100	0.163	1.015
1983-1988	0.306	-0.443	0.661	0.120	0.168	1.072
1989-1993	0.241	-0.549	0.575	0.136	0.172	1.081
1994-1998	0.202	-0.600	0.536	0.148	0.174	1.079
1999-2003	0.194	-0.647	0.514	0.154	0.174	1.074
2004-2008	0.172	-0.676	0.485	0.160	0.175	1.079
2009-2013	0.159	-0.699	0.466	0.164	0.175	1.082

This table reports five-year averages calculated using the model-generated data where both selection mechanisms are in place. Column I reports the relative size at entry, column II reports the relative productivity shock at entry (z), Column III reports the relative turnover ratio at entry, Column IV reports the average cash-to-assets ratio, and columns V and VI report the average and relative cross-sectional disperson of the sales' growth rate, respectively.

2009-2013. In any model with a decreasing returns-to-scale technology assumption, the turnover ratio is a proxy for firm-level productivity and profitability. Because of this link, the turnover ratio should be an important empirical determinant of the cash-to-assets ratio at the firm level.[15] These predictions are consistent with the findings in Fama and French (2004), who document a steady decrease in size and profitability during the 1980–2001 period, and highlight the role of new listings.

Second, the two selection mechanisms, in addition to generating a steady increase in the cash-to-assets ratio (column IV), deliver an increase in the dispersion of the sales growth rate that is qualitatively consistent with the data (column V), as we will show in Table 5 in section 3.[16] Without changing the volatility parameter for the productivity shock in the model, the *intra-industry* selection mechanism allows smaller firms to go public. Because of decreasing returns to scale, smaller firms are characterized by higher and more volatile growth rates. This feature is responsible for the steady increase in the dispersion of sales' growth rates, which is entirely driven by sales of new economy firms becoming relatively more volatile (column VI).[17]

[15] Notice that, given the stylized nature of the model, sales and profit do coincide.

[16] The sales growth rate is defined in Section A.2.

[17] Davis et al. (2007) show how, contrary to what happened in the private sector, the cross-sectional dispersion of firm growth rates for publicly listed U.S. companies has increased over the 1978–2004 period. Brown and Kapadia (2007) show the increase in firm-specific risk is a direct result of riskier firms going public, hinting at a selection mechanism.

To sum up, our model suggests that any data analysis should pay attention to entry decisions of firms, particularly when a specific firm type (here R&D–intensive firms) becomes increasingly dominant in the sample. Inference based on exogenous changes in deep parameters (e.g., an increase in the cash–flow volatility parameter over time) can be confounded with factors that are outside the firm's optimization problem, but are due to changes in the selection process into the stock market. For example, empirical estimates could assign too much importance to increased uncertainty when in fact selection contributes to the rise in cash-flow volatility and cash holdings.

3 The empirical evidence on sample selection effects

In this section, we explore the model's predictions by studying how sample selection affects the secular increase in the cash–to–assets ratio. The data corroborate what the model suggests: most of the action for the change in the cash–to–assets ratio is at the entry margin and is driven by an increasing share of smaller and less profitable R&D–intensive firms with higher cash-to-assets ratios that went public during the last 35 years.

We first describe the data set and definitions. Then we show a negative time trend exists in the cash–to–assets ratio at the firm level, whereas pooled OLS regressions show a positive time trend. A negative firm-level trend together with a positive trend in the cross-section suggests the secular increase in cash is mainly a byproduct of sample selection. We isolate the effect of sample selection on the positive time trend using a simple accounting decomposition and show that newly listed R&D–intensive firms are responsible for the bulk in the increase of the average cash-to-assets ratio.[18] We conclude our analysis by providing evidence for the two selection mechanisms discussed in the model and by studying the determinants of R&D–intensive firms' cash holdings before they go public.

[18] We rule out firm exit as a driver of the secular increase in the cash–to–assets ratio (see figure 12 in the appendix). We find the average cash–to–assets ratio at exit is close to the cross-sectional average of the cash–to–assets ratio. This behavior is consistent with exit being i.i.d.

3.1 R&D–intensive firms: Data and definitions

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-U.S.-incorporated firms, and those not traded on the three major exchanges: NYSE, AMEX, and NASDAQ.

R&D–intensive firms are firms that belong to an industry (using the three-level-digit *SIC* code) that has 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.[19]

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 et al. (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.[20]

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 not essential to our results. We define an *entrant* as a firm that reports a fiscal year-end value of the stock price for the first time (item $PRCC\_F$).[21]

[19]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%).

[20]Differently from Bates et al. (2009), we do not to 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.

[21]Our results are robust to using value-weighted data (e.g., Table 11 in the Appendix) or defining entry based on the IPO dates provided by Jay Ritter. http://bear.warrington.ufl.edu/ritter/ipodata.htm.

Table 3: Estimating the Time Trend

	Pooled OLS		Firm-by-Firm							
	All I	All II	All III	All IV	Young V	Young VI	Mature VII	Mature VIII	Old IX	Old X
Trend	0.418***	0.055***	-0.497***	-0.267***	-0.461***	-0.239***	-0.226***	-0.115***	0.005	0.001
	0.007	0.006	0.034	0.048	0.037	0.053	0.026	0.037	0.239	0.033
Trend X R&D		0.605***		-0.463***		-0.447***		-0.224***		0.007
		0.013		0.068		0.075		0.052		0.048
R&D Dummy		4.579***		20.711***		20.760***		0.180***		11.100***
		0.253		0.587		0.642		0.000		0.910
Constant	10.661***	9.371***	21.920***	11.640***	21.581***	11.276***	20.234***	11.446***	14.648***	9.510***
	0.123	0.122	0.325	0.413	0.350	0.453	0.387	0.505	0.474	0.619
Observations	85,947	85,947	(5,496; 16)		(5,496; 5)		(3,614; 9)		(1607; 13)	
Adjusted R^2	0.035	0.185	0.295		0.418		0.312		0.291	

We estimate the following baseline linear equation:

$$CH_{i,t} = \alpha + \beta t + \varepsilon_{i,t}$$

The dependent variable is the cash–to–assets ratio defined as Compustat item CHE divided by Compustat item AT and expressed in percentage terms. The sample includes Compustat firm-year observations from 1979-2013 with at least five years of observations, positive values for assets and sales, excluding financial firms (SIC codes 6000 to 6999) and utilities (SIC codes 4000 to 4999). We also sort firms into R&D– versus non-R&D–intensive, as discussed in section 3.1. In columns I and II, we run pooled OLS regressions and we normalize the year 1979 to zero. In columns III-X, we run a linear regression for each firm in our sample and set the time variable equal to zero the first year the firm appears in the sample. *Young firms* are firms that have been public for at most five years, *mature firms* are firms that have been public for more than five years but less than 16 years, and *old firms* are firms that have been public for at least 16 years. For the firm-by-firm regressions, we report the number of individual firms in the sample together with the average number of observations for each firm. The reported R^2 for the firm-by-firm regressions is the average R^2 across all the regressions. We report robust standard errors. * denotes significance at the 10% level, ** denotes significance at the 5% level, and *** denotes significance at the 1% level.

3.2 The time trend in cash holdings

The model presented in Section 2 is able to generate a positive trend in cash holdings despite the mean-reverting nature of the cash-to-assets ratio at the firm level, which means that new entrants deplete cash at a lower rate than the rate at which they increase cash at entry, as illustrated in Figure 7. In this section, we provide evidence for this selection-based explanation.

We first estimate the time trend in the cash–to–assets ratio using all firms over the period 1979–2013. The resulting trend is positive: cash holdings represented around 11% of total assets for the typical firm in 1979, and they have increased by 14% over the subsequent 35 years (column I of Table 3). Column II of Table 3 shows the differences in the time trend across sectors by including a dummy variable that takes a value of zero if a firm is non-R&D–intensive, and 1 otherwise. The estimated slope for the R&D sector is one order of magnitude larger than the estimated slope for the non-R&D sector (66 b.p. vs. 5.5 b.p.). The implied increase in cash holdings for the non–R&D sector over the 35-year period is very small (around 2%), while cash holdings in the R&D sector surged from an average value of 14% in 1979 to an average value of 35% in 2013. The secular increase in the cash-to-assets ratio appears to be a phenomenon that pertains almost exclusively to the R&D–intensive sector.

Pooled OLS regressions allow us to identify R&D–intensive firms as the driver of the secular increase in cash holdings. However, the cash–to–assets ratio is fairly persistent (see also Figure 13 and Lemmon et al. (2008)), and pooled OLS regressions are not conclusive with regard to each firm's individual cash–to–assets evolution. In fact, incumbent R&D–intensive firms could have indeed increased their cash–to–assets ratios over time. To address the persistence issue, we perform firm–by–firm regressions and report average values of the estimated coefficients. We set the time variable equal to zero the first year the firm appears in the sample. In this way, we control for the cash holdings at entry at the firm level. The results show a negative change in average cash holdings for incumbents. The estimated yearly within-firm change in average cash holdings over 35 years is -50 b.p. (column III). Column

IV shows that R&D–intensive firms start with much larger cash balances and deplete cash faster than non-R&D–intensive firms.

The estimates in columns III and IV represent the trend for an average public firm during the 1979–2013 period. In the remaining columns of Table 3, we estimate the time-trend-by-age category because firms might not be at their *steady-state* cash level shortly after the IPO. In particular, we define *young firms* as firms that have been public for at most five years, *mature firms* as firms that have been public for more than five years but less than 16, and *old firms* as firms that have been public for at least 16 years. The results in columns V-VIII show that (i) both young and mature firms deplete cash after an IPO, (ii) young firms deplete cash faster than mature firms, and (iii) the estimated slope for R&D–intensive firms is twice as large as the estimated slope for non–R&D–intensive firms. No significant time trend in cash holdings exists for old firms (see columns IX and X) regardless of the sector.

The data show that a positive time trend in average cash holdings exists despite a negative time trend within firms. As in the model, this feature is a result of newly listed firms increasing their cash holdings at entry faster than the rate at which incumbents deplete theirs.[22]

3.3 Decomposing the change in the average cash ratio

In this section, we directly measure the contribution of sample selection to the secular increase in average cash holdings. Using a simple accounting decomposition, we find selection contributes by more than 200%, whereas the within-firm change in cash holdings contributes a negative 120%.

The accounting decomposition allows us to isolate the part of the change in the average cash–to–assets ratio coming from changes within incumbent firms from changes due to new firms (entrants). The change in the average cash–to–assets ratio ΔCH_t between time $t-1$

[22]In the Appendix, we show in Table 9 which entering cohorts have mattered for the secular trend.

and t can be written as

$$\Delta CH_t = \underbrace{\left(\frac{N_t^I}{N_t}CH_t^I - \frac{N_t^I}{N_{t-1}}CH_{t-1}^I\right)}_{\text{within change}} + \underbrace{\left(\frac{N_t^E}{N_t}CH_t^E - \frac{N_{t-1}^X}{N_{t-1}}CH_{t-1}^X\right)}_{\text{selection effect}},$$

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. N^j denotes the number of incumbents ($j = I$), entrants ($j = E$), and exitors ($j = X$).[23]

The selection effect can be further split between the selection effect generated by R&D–intensive firms and the selection effect generated by non-R&D–intensive firms

$$\Delta CH_t = \left(\frac{N_t^I}{N_t}CH_t^I - \frac{N_t^I}{N_{t-1}}CH_{t-1}^I\right) + \sum_{i=\{R\&D;nonR\&D\}} \left(\frac{N_t^{E_i}}{N_t}CH_t^{E_i} - \frac{N_{t-1}^{X_i}}{N_{t-1}}CH_{t-1}^{X_i}\right).$$

In Figure 8, we plot the cumulative change in average cash holdings over time, whereas Table 10 in the appendix reports the quantities.[24] The selection effect due to new entrants accounts for more than 200% of the secular increase in cash holdings (0.329), whereas the contribution of the *within change* is actually -117% (-0.178). These quantities are consistent with the results presented in the previous section.[25]

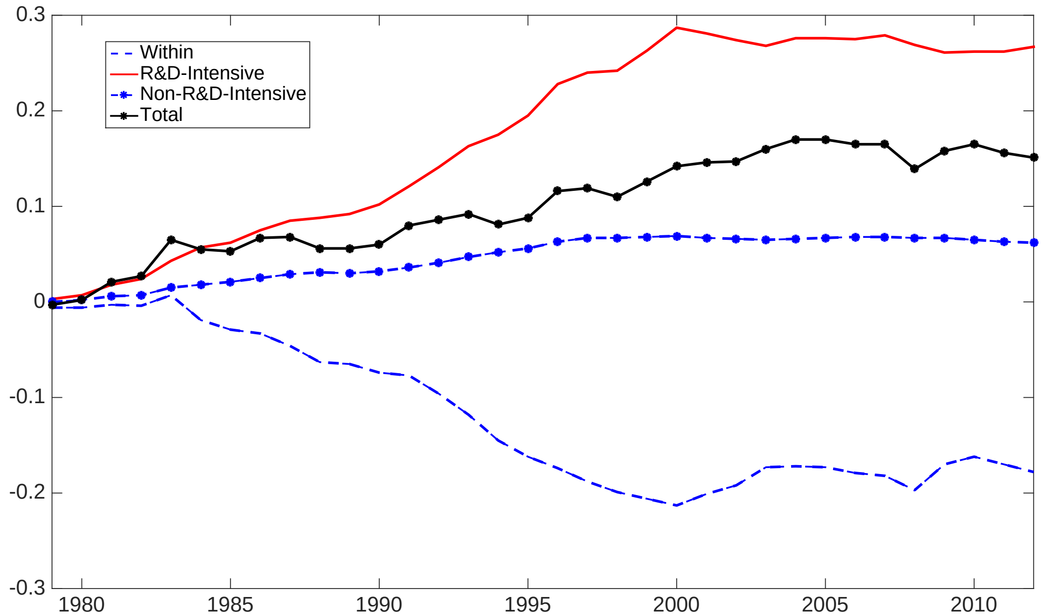
Table 4 shows the results when we apply our decomposition approach using industries defined at the three-digit SIC codes. The two sectors that play a key role in determining the selection effect are Drugs (SIC 283) and Computer and Data Processing Services (SIC 737). On their own, they explain around 50% of the overall selection effect, whereas the

[23]More precisely, consider the change in average cash holdings between time t and time $t-1$: $\Delta CH_t = CH_t - CH_{t-1}$. Let N_t^I be the firms publicly traded between time $t-1$ and t (the incumbents), and let N_{t-1}^X be the firms that exit between time $t-1$ and t. Then the average cash holdings at time $t-1$ are $\frac{N_t^I}{N_{t-1}}CH_{t-1}^I + \frac{N_{t-1}^X}{N_{t-1}}CH_{t-1}^X$, where $N_{t-1} = N_t^I + N_{t-1}^X$, CH_{t-1}^I is the average cash holdings of incumbents at time $t-1$, and CH_{t-1}^X is the average cash holdings at time $t-1$ of firms that exit between time $t-1$ and t. Let N_t^E be the firms that enter into Compustat at time t. Then the average cash holdings at time t are $\frac{N_t^I}{N_t}CH_t^I + \frac{N_t^E}{N_t}CH_t^E$, where $N_t = N_t^I + N_t^E$, CH_t^I is the average cash holdings of incumbents at time t, and CH_t^E is the average cash holdings at time t of firms that enter at time t.

[24]Table 11 in the appendix shows the results are also robust to value-weighted cash ratios.

[25]The estimated change (within change) in average cash over 35 years implied by column III of Table 3 is -0.175. The contribution of selection to the secular increase in cash holdings can be calculated as the difference between the estimated change using pooled OLS (0.147, from column I of Table 3) and the one using firm–by–firm regressions (-0.175). The resulting quantity is 0.322, a value very similar to the one we obtain with the accounting decomposition.

Figure 8: Cash-Change Decomposition



This figure reports the cumulative change in average cash holdings over the sample period together with its three components: the cumulative change due to incumbents (labeled "within"), the cumulative change due to R&D–intensive entrants, and the cumulative change due to non-R&D–intensive entrants.

remaining five R&D–intensive sectors identified by Brown et al. (2009) account for 25%. When we consider all the industries, the R&D–intensive sector accounts for the bulk (82%) of the selection effect. In other words, the secular increase in cash holdings is driven by R&D–intensive firms that enter with a progressively higher cash–to–assets ratio.

3.4 Controlling for selection: empirical evidence

So far, our empirical evidence shows the importance of newly listed firms for the secular increase in cash holdings. Our stylized model explores how the change in the composition and identity of firms that enter the stock markets affects this increase. In this section, we assess whether the impact of these two selection mechanisms is consistent with the model's predictions.

The model predicts that a change in the composition at entry plays no role in shaping the secular increase in cash, but it provides an amplification mechanism when coupled with the

Table 4: 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%
Communications Equipment (SIC 366)	0.010	2.92%
Measuring and Controlling Devices (SIC 382)	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; nonR&D intensive sector}. The reported number is cumulative changes over the period 1979-2013.

entry of relatively smaller and less profitable firms. This second selection effect is necessary to generate increasing cash holdings at entry over time that leads to a steady increase in the average cash-to-assets ratio in the cross section. We control for these two selection mechanisms by assuming that over the period 1979-2013, (1) R&D–intensive entrants in the stock market have an average cash-to-asset ratio as in 1974-1978 and (2) the proportion of R&D–intensive entrants is the same as in 1974-1978. According to the model (see Table 2), imposing (1) is sufficient to shut down the secular increase in cash holdings and the associated increase in sales' growth rate dispersion. In addition, we should observe relatively larger and more efficient R&D–intensive entrants only when the first mechanism is in place, whereas the change in composition has no role other than amplifying the effect of a change in the type of R&D–intensive firm that goes public.

Table 5 reports our empirical results. We start by analyzing the full sample of firms in Panel A. The data show how the secular increase in the cash–to–assets ratio is connected to a positive trend in sales' dispersion and to a relative decrease both in size and efficiency of R&D–intensive entrants, indicative of a change in the type of R&D firms that became public.

In Panel B, we study how this link changes after controlling for selection. The data for Panel B are a random sample of the full dataset under the two restrictions discussed above. We repeat the exercise 500 times and report average values across simulations. Moreover, we ensure the fraction of entrants since 1979 corresponds to the one in the data. This exercise shows that without the help of selection, the increase in the cash-to-assets ratio is negligible and fluctuates around 11% for the first four sub-samples and slightly increases for the last three (column I). At the same time, the increase in sales' dispersion virtually disappears (column II) because R&D–intensive firms do not experience an increase in relative dispersion (column III). Panel B shows that selection at entry is a key driver for the secular trends in cash holdings and firm-level volatility. When we restrict R&D–intensive firms to enter with the same cash–to–assets ratio (columns V and VI) and in the same proportion (column VII), R&D–intensive entrants are relatively larger (column VIII) and more efficient (column IX).

In Panel C, we analyze the importance of the across-industry selection mechanism. To this end, we randomly sample the data but only place restriction (1); that is, we shut off the within-industry selection effect. A change in the composition of R&D–intensive entrants alone contributes very little to the secular increase in cash holdings, as the model predicts. Similar to the results in Panel B, when we control for within-industry selection alone, the sample exhibits R&D–intensive entrants that are relatively larger and more profitable (i.e., larger turnover ratio) compared to the actual data (see Panel A). The data thus support the prediction that generating a positive trend in cash holdings without the entry of smaller and less profitable firms is difficult.

Table 5: Which Selection Mechanism?

	All firms				Entrants				
	CH	Sales' vol	Sales' vol (Relative)	% Entrants post 1979	CH Non-R&D	CH R&D	% R&D	Size (Relative)	Turnover (Relative)
Panel A	Panel A: Full Sample								
	I	II	III	IV	V	VI	VII	VIII	IX
1979-1983	0.113	0.289	1.010	0.259	0.184	0.287	0.544	0.591	0.791
1983-1988	0.141	0.334	1.152	0.507	0.147	0.324	0.454	0.262	0.646
1989-1993	0.156	0.327	1.347	0.685	0.150	0.429	0.533	0.273	0.638
1994-1998	0.193	0.382	1.413	0.781	0.173	0.463	0.558	0.302	0.614
1999-2003	0.230	0.427	1.549	0.810	0.201	0.557	0.730	0.195	0.434
2004-2008	0.245	0.352	1.540	0.823	0.186	0.550	0.603	0.154	0.417
2009-2013	0.247	0.387	1.642	0.826	0.122	0.549	0.659	0.147	0.430
	Panel B: Random Sample Controlling for Selection								
	I	II	III	IV	V	VI	VII	VIII	IX
1979-1983	0.103	0.288	0.921	0.254	0.183	0.121	0.401	0.826	1.003
1983-1988	0.114	0.315	0.993	0.483	0.147	0.123	0.401	0.428	0.817
1989-1993	0.110	0.285	0.993	0.667	0.149	0.121	0.401	0.961	0.929
1994-1998	0.115	0.322	1.003	0.766	0.174	0.119	0.400	0.605	0.938
1999-2003	0.130	0.341	1.038	0.794	0.202	0.125	0.400	0.918	0.694
2004-2008	0.148	0.284	1.043	0.817	0.186	0.120	0.401	0.700	0.677
2009-2013	0.148	0.307	1.100	0.828	0.121	0.119	0.398	0.497	0.664
	Panel C: Across-Industry Selection Effect								
	I	II	III	IV	V	VI	VII	VIII	IX
1979-1983	0.104	0.290	1.014	0.271	0.185	0.122	0.543	0.840	0.991
1983-1988	0.117	0.315	1.030	0.517	0.149	0.122	0.453	0.431	0.818
1989-1993	0.112	0.286	1.053	0.694	0.150	0.116	0.530	0.941	0.927
1994-1998	0.119	0.320	1.058	0.779	0.173	0.114	0.557	0.623	0.928
1999-2003	0.139	0.347	1.170	0.805	0.200	0.143	0.682	0.694	0.699
2004-2008	0.160	0.284	1.111	0.822	0.186	0.137	0.565	0.536	0.687
2009-2013	0.161	0.312	1.209	0.830	0.124	0.126	0.653	0.472	0.686
	Panel D: Within-industry selection effect								
	I	II	III	IV	V	VI	VII	VIII	IX
1979-1983	0.112	0.294	0.922	0.269	0.184	0.289	0.400	0.589	0.793
1983-1988	0.139	0.338	1.119	0.534	0.148	0.324	0.399	0.264	0.645
1989-1993	0.146	0.321	1.282	0.700	0.149	0.429	0.400	0.295	0.641
1994-1998	0.167	0.363	1.329	0.780	0.173	0.461	0.400	0.299	0.617
1999-2003	0.184	0.378	1.373	0.796	0.202	0.559	0.395	0.202	0.432
2004-2008	0.202	0.322	1.415	0.810	0.187	0.551	0.396	0.147	0.412
2009-2013	0.201	0.346	1.513	0.811	0.122	0.552	0.397	0.125	0.427

This table reports five-year averages under different bootstrap sampling techniques. Panel A is the full sample. Panel B presents averages from a bootstrapped sample that controls for both selection mechanisms by imposing two restrictions: (1) The average cash ratio of entrants is close to the cash ratio of entrants in the 1974-1978 period and (2) the industry composition of R&D and non-R&D firms is also at the pre-1979 level. Panel C presents averages from a bootstrapped sample that controls for the within-industry selection mechanism by imposing restriction (1). Panel D controls for the across-industry selection mechanism by imposing restriction (2). All random samples keep the fraction of entrants since 1978 as in the full sample. Column I reports the average cash-to-assets ratio. Column II reports the relative cross-sectional disperson of the sales' growth rate. Column III reports the fraction of entrants since 1979. Columns IV and V report average cash holdings at entry of non-R&D-intensive and R&D-intensive firms, respectively. Column VI reports the fraction of R&D-intensive entrants. Columns VII and VIII report the relative size and the relative efficiency, measured by the relative turnover ratio of R&D-intensive entrants.

In Panel D, we shut off the across-industry selection mechanism and turn on the intra-industry selection mechanism by randomly sampling the data from the full sample but keeping the proportion of R&D–intensive entrants to non-R&D–intensive entrants constant. The increase in the cash-to-assets ratio is quite large, and the relative size and efficiency are falling, as the model predicts. At the same time, without the amplification effect provided by the compositional change, the intra-industry selection mechanism cannot explain the entire change in the average cash-to-assets ratio.

3.5 What determines the cash ratio at entry?

The results in the previous section highlight a tight connection between the cash-to-assets ratio at entry for R&D–intensive firms and our proxy for firm-level efficiency (i.e., the turnover ratio). In this section, we compare the explanatory power of the latter variable with other important determinants of corporate cash holdings.

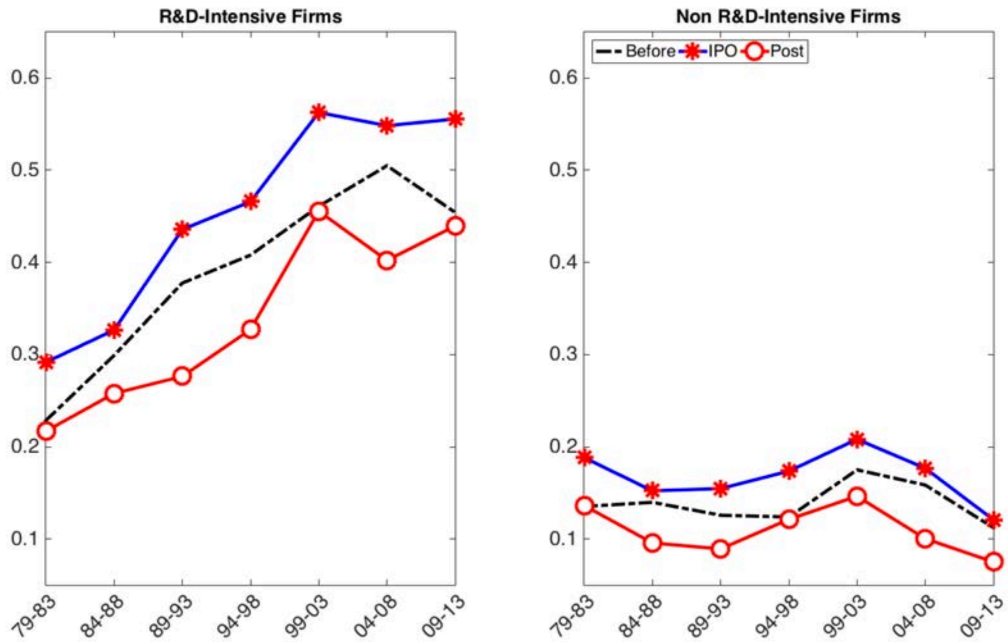
First we show in Figure 9 firms' average cash holdings for each cohort of entrants around the IPO year. For both sectors, average cash holdings are smaller before the IPO year and decrease the year after the IPO below their pre–IPO values.[26] However, only the R&D–intensive sector (left panel) shows a secular trend in average cash holdings before the IPO year, a phenomenon that clearly does not depend on a higher retention of IPO proceeds.

Table 6 studies what determines the cash–to–assets ratio entry by focusing on quantities in the fiscal year that precede the IPO year. We consider widely studied determinants in the cash holding literature (e.g., Azar et al. (2016) and Bates et al. (2009)) and include the turnover ratio as a proxy for the underlying total revenue productivity shock, as suggested by the model. In column I, we consider all variables. Only the T-bill rate does not enter significantly.[27] In column II, we report the Shapley-Owen's R-square decomposition (Israeli (2007) and Huettner and Sunder (2012)) to measure each individual independent variable's

[26]We can perform these calculations because Compustat reports up to three years of firms' accounting data prior to their IPO.

[27]Following Azar et al. (2016), we include the T-bill as a main predictor of corporate cash holdings. Unlike Azar et al. (2016), we cannot compute the cost of carry cash at the individual firm level given the lack of observations in the years preceding the IPO.

Figure 9: Reduction in entry costs for new economy firms



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).

contribution to the goodness of fit. Three variables stand out: net working capital, leverage, and the turnover ratio. We consider only these variables in column III and show they can explain 53% of the variation of cash at entry compared to 61% when we use all the regressors. In column V, we also include R&D expenditures, which have been widely associated with the secular increase in cash holdings (e.g., Falato et al. (2013)). The addition of the R&D–to–assets ratio does not change the marginal contribution of other variables dramatically, and, most importantly, the share of variability explained by the turnover ratio is almost unaffected. In the last regression, we show the stand-alone explanatory variable of the turnover ratio is quite large given that this variable can explain 30% of the variation in corporate cash holdings at entry for R&D–intensive firms.

Table 6: What drives the cash ratio?

VARIABLES	CH	%R2	CH	%R2	CH	%R2	CH
	I	II	III	IV	V	VI	VII
Tbill (3-Month)	-0.137	2.418					
	(0.160)						
Size	-0.019***	1.925					
	(0.003)						
Cash Flows	0.066***	4.829					
	(0.016)						
NWC	-0.323***	12.64	-0.373***	22.230	-0.318***	17.889	
	(0.021)		(0.019)		(0.019)		
R&D	0.210***	8.633			0.168***	11.370	
	(0.027)				(0.019)		
Dividend	-0.047***	2.117					
	(0.016)						
Market / Book	0.001	1.337					
	(0.001)						
CAPEX	-0.606***	5.200					
	(0.055)						
Leverage	-0.630***	27.933	-0.757***	38.907	-0.733***	36.128	
	(0.024)		(0.023)		(0.023)		
Acquisition	-0.643***	4.802					
	(0.060)						
Turnover	-0.167***	28.168	-0.168***	38.864	-0.160***	34.614	-0.243***
	(0.007)		(0.006)		(0.006)		(0.07)
Constant	0.658***		0.650***		0.611***		0.599***
	(0.011)		(0.006)		(0.008)		(0.07)
Observations	2,314		2,773		2,773		2,923
R-squared	0.610		0.530		0.543		0.296

This table reports cross-sectional regressions where the dependent variable is the cash-to-assets ratio (Compustat item *che* divided by *at*) in the fiscal year before a company goes public. We only consider firms in the R&D-intensive sector. The independent variables are Size (log of real total assets, Compustat item *at*), Cash Flows ((*oibdp* - *xint* - *dvc* - *txt*)/*at*)), Net Working Capital ((*wcap-che*)/*at*), R&D over sales (*xrd*/*sale*, we set *xrd* to zero when missing); Dividend Dummy (takes the value of 1 if $dvc > 0$ and zero otherwise), Market-to-Book ratio ((*at*+*prcc_f***csho*-*ceq*)/*at*), Capital expenditures (*capx*/*at*), Leverage ((*dltt*+*dlc*)/*at*); Acquisition (*aqc*/*at*), and Turnover ratio (*sale*/*at*). "Observations" reports the number of R&D-intensive firms for which we have observations on accounting quantities in the fiscal year before the IPO. For each of the first three regressions, we report the contribution of each individual independent variable using the Shapley-Owen decomposition (Huettner and Sunder (2012)). For the regression in column VII, the Shapley-Owen decomposition delivers a value of 100 and we do not report it. We report robust standard errors. * denotes significance at the 10% level, ** denotes significance at the 5% level, and *** denotes significance at the 1% level.

Table 7: What explains the change in the cash ratio of entrants

	I	II	III	IV	V
Turnover	-0.301***				-0.253***
	(0.036)				(0.049)
R&D		0.420*			0.201
		(0.212)			(0.171)
NWC			-0.673***		-0.031
			(0.225)		(0.252)
Leverage				-0.828***	-0.449**
				(0.204)	(0.205)
Constant	0.005	0.011	0.005	0.009	0.003
	(0.008)	(0.012)	(0.011)	(0.011)	(0.008)
Observations	34	34	34	34	34
R-squared	0.553	0.061	0.156	0.218	0.620

This table reports time-series regressions where the dependent variable is the change in the average cash-to-assets ratio before IPO over the period 1979-2013. We only consider firms in the R&D-intensive sector. The independent variables are also changes in average values calculated the year before IPO. The variable definitions can be found in Table 6. We report robust standard errors. * denotes significance at the 10% level, ** denotes significance at the 5% level, and *** denotes significance at the 1% level.

All of the key variables identified in Table 6 have a pronounced time trend over the period 1979-2013. In Table 7, we address the problem of having spurious correlations due to common time trends by regressing the change in entrants' average cash–to–assets ratio on the change in the average values of the turnover ratio, R&D–to-assets ratio, net working capital, and leverage, respectively.

Our results show the change in the average turnover ratio alone explains more than half of the variation in the average cash-to-assets ratio's fluctuations at entry over the period 1979-2013 (column I). The other variables have a much smaller individual explanatory power, with the only exception of leverage that can individually explain around 20% of the variation in the change in the average cash-to-assets ratio at entry (column V). In column VI, we consider the joint explanatory power of all the variables. As we can see, only the turnover ratio and leverage come out significant and the model explains 62% of the variation in the data, a small improvement over the model that only considers the turnover ratio. This last exercise provides additional evidence on the importance of the turnover ratio in shaping the dynamics of the average cash-to-assets ratio over the last 35 years.

4 Conclusion

This paper finds that sample selection has been a key driver of the increase in the average cash–to–assets ratio for U.S. public companies over the last 35 years. While new entrants to the stock market have increased their cash–to–assets ratios, the typical U.S. public company experiences a decline in cash holdings over time. The selection effect is powerful enough to reverse the negative within-firm effect and to generate a secular increase.

A stylized firm industry model with endogenous entry allows us to study how selection mechanisms can shape the average cash–to–assets ratio. More than a shift in the composition of R&D–intensive firms, a shift toward smaller, initially less productive, but higher-growth-potential firms is the key driver of higher cash balances at IPO. This mechanisms is backed up by the data as we show with bootstrap sampling techniques. The data also show the turnover ratio, as a proxy for firm-level productivity, is a key predictor for cash ratios at entry, as our model suggests.

All in all, our results suggest a new direction in the debate about the causes of the secular increase in the corporate cash–to–assets ratio and other observed changes in investment and financing practices. Instead of focusing on factors that influence incumbents' investment and financing decisions, we advocate for a shift of research efforts toward understanding why more R&D–intensive firms go public and why they do so with higher cash–to–assets ratios over time.

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A On the Model

This appendix section presents the details of the model presented in section 2.

A.1 Firm industry equilibrium

Denote ω as the fraction of old-economy firms. Given ω and the riskless rate R, a recursive competitive equilibrium consists of (i) value functions $V^i\left(k_i, s_{i,} z\right)$ and $V^{E,i}(q)$, (ii) policy functions $l_i^{'}\left(k_i, s_{i,} z\right)$ and $x_i'\left(k_i, s_{i,} z\right)$, and (iii) bounded sequences of incumbents' measure $\{\Gamma_t^i\}_{t=1}^{\infty}$ and entrants' measures $\{\varepsilon_t^i\}_{t=0}^{\infty}$ $\forall i \in \{o, n\}$ such that

1. $V^i\left(k_i, s_{i,} z\right)$, $l_i^{'}\left(k_i, s_{i,} z\right)$, and $x_i'\left(k_i, s_{i,} z\right)$ solve the incumbents problem $\forall i \in \{o, n\}$.

2. $V^{E,i}\left(q\right)$, $s_i^{'}\left(q\right)$ and $x_i'\left(q\right)$ solve the entrants problem $\forall i \in \{o, n\}$.

3. For all Borel sets $Z \times K \times L \times X \times \Re$ and $\forall t \geq 0$ and $W = K \times L$

$$\varepsilon_{t+1}^i(W) = M_i \int_Z \int_{B^{E_i}(W)} dQ(q) d(F(z'^*|q)).$$

   where $B^{E_i}(W) = \left\{ (s_i'(q), x_i'(q)) \text{ s.t. } l_i'(q) \in L,\ x_i'\left(q\right) \in X \text{and } V^{E,i} \geq c_{e,i} \right\}$ denotes the policy functions of entrants.

4. For all Borel sets $Z \times K \times L \times X \times \Re$ and $\forall t \geq 0$ and $W = K \times L$,

$$\Gamma_{t+1}^i(W') = (1-\phi) \int_Z \int_{B^i(W)} d\Gamma_t^i(W) dF(z'|z) + \varepsilon_{t+1}^i(W),$$

   where $B^i(W)$ denotes the policy functions of incumbents and $\omega = \Gamma_{t+1}^o(W')/(\Gamma_{t+1}^n(W') + \Gamma_{t+1}^o(W'))$.

The distribution of firms evolves in the following way. A mass of entrants receives a signal and some decide to enter. The signal q determines the productivity level of the following period. Firms choose savings and capital investment. These choices determine the expected net worth for the following period. Conditional on not exiting, incumbent firms pick the period's investment, internal, or external funds. The shocks follow a Markov distribution.

A.2 Parametrization

We parametrize the model at an annual frequency using calibrated parameters that match key features of U.S. public companies. To highlight the role of selection, we calibrate the parameters using the period 1959-1979, i.e. before the large increase in cash–holdings.

A few standard parameters are set to values used in the literature. Following Hennessy and Whited (2007), we set the decreasing returns-to-scale parameter to 0.62 and the depreciation rate to 0.15. Following Riddick and Whited (2009), we set the annual risk-free interest rate to 4% and the conditional standard deviation of the idiosyncratic shock to 0.121. Table 1 reports the parameter values and their targets.

We calibrate the remaining parameters to match key moments, using data from the period 1959–1979. The proportion of potential entrants of type old (ω) is set to 0.668. This value allows us to replicate the composition of publicly traded firms during the period 1959-1979. We set the persistence parameter equal to 0.90 – a value within the estimates provided by Hennessy and Whited (2007) – to match the standard deviation of the sales' growth rate during the period 1959-1979. We define the latter quantity as $\Delta y_t = \frac{y_t - y_{t-1}}{0.5 y_{t-1} + 0.5 y_{t-1}}$.

Then we calibrate a set of parameters to replicate key cash holdings moments for publicly traded firms in 1979. First, we calibrate the cost of carrying cash inside the firm, ν, to match the average cash–to–assets ratio. Second, we choose a number for the value of staying private to match the average cash–to–assets ratio at entry. The proportional equity issuance cost (κ) is set to match the average equity-to-assets ratio over the period 1959-1979. We define the cash–to–assets ratio in the model as cash holdings divided by the beginning of the period capital plus cash holdings, whereas the equity–to–assets ratio as equity issuance divided by the beginning of the period capital plus cash holdings.

The parameter that governs the investment adjustment cost is set to deliver an investment-rate standard deviation close to the one found in the data over the period 1959-1979.[28]

The parameter that governs the shape of the Pareto distribution, ξ, over the set of signals is chosen to match the size of entrants relative to the size of incumbents of age 5. We measure

[28] We measure the investment rate in the data as capital expenditures (Compustat item *capx*) divided by the previous period value of net property, plant, and equipment (item *ppent*).

firm size using total sales.[29] Panel B of Table 1 reports the simulated moments together with their empirical counterpart.

To conclude, we set the exogenous exit rate (λ) to 7%, a value that delivers an age (i.e., years since entry) distribution close to the age distribution in Compustat over the period 1979-2013 (Panel C of Table 1). In our model (as in the data), the years since entry distribution matters because firms that recently IPOed tend to be smaller and have larger cash–to–assets ratios. For this reason, we choose an exit rate that delivers an age distribution as close as possible to the data.

Solution

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 the capital grid using 200 grid points, the net leverage grid for old-economy firms using 100 grid points, and the cash grid for new-economy firms using 100 grid points. We also scale the revenue function so that the capital choice is between zero and 1.

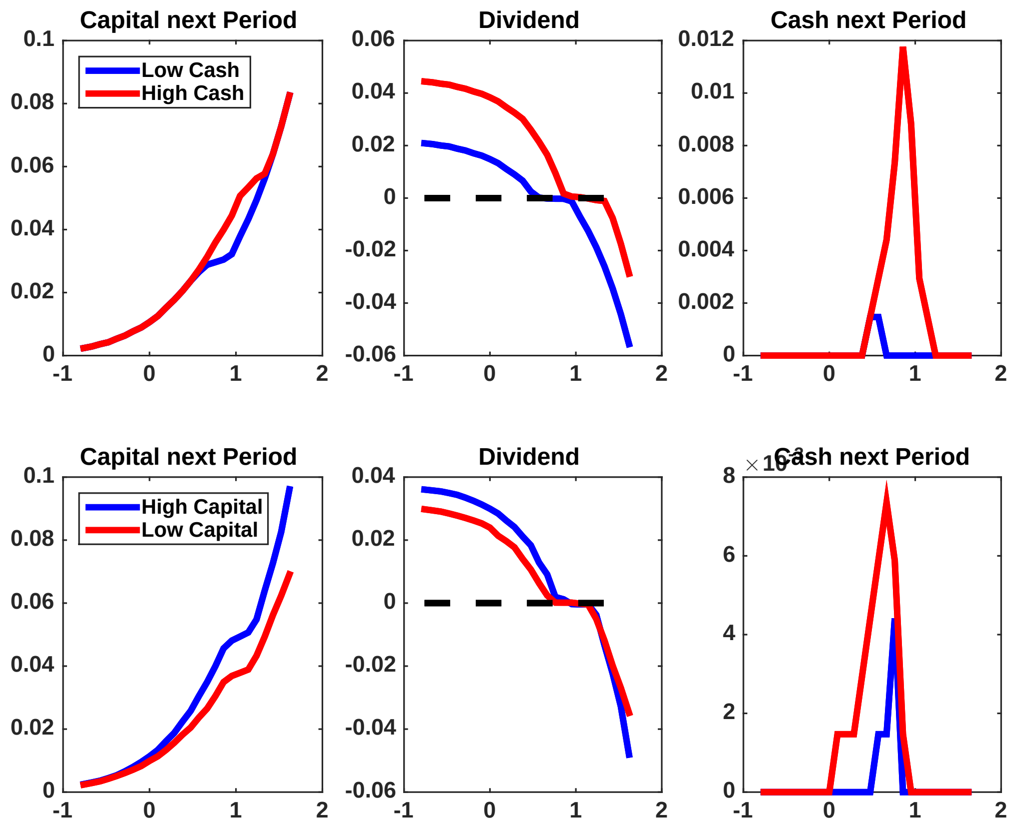
We also solve the entrant problem by value function iteration. We discretize the signal space using 100 grid points. The lower (upper) bound of the signal grid coincides with the lower (upper) bound of the firm-level shock grid. We use a discrete version of the Pareto distribution to allocate the mass of potential entrants over the signal space.

A.3 Incumbent policy functions

Figure 10 illustrates the policy functions for an incumbent firm as a function of the firm–level shock. The top panels are policies for two firms that have the same size, as measured by their beginning of the period capital, and only differ in their beginning of the period cash balances. The left panel shows these two firms choose the same capital next period if they are both distributing dividends or issuing equity. For small values of the shock, both firms have the same investment and financing policies. In particular, when the

[29] We assume $Q(q) = 1 - (\underline{q}/q)^{\xi}, \xi > 1$, where $\underline{q}$ is the lower bound of the signal grid. For further details, see Appendix B in Clementi and Palazzo (2016).

Figure 10: Policy Functions



The figure reports the policy functions as a function of the firm-level shock for a new-economy firm. The left panels depict the optimal capital choice, the middle panels depict the distributed dividends, and the right panels depict the optimal saving policy. The top panels report the policies for a high-cash firm (red line) and a low-cash firm (blue line), while considering the same level of beginning-of-the-period capital stock. The bottom panels report the policies for a low-capital firm (red line) and a high-capital firm (blue line), while considering the same level of beginning-of-the-period cash.

productivity shock is very low, both firms find it more convenient to distribute dividends rather than to invest. As the productivity increases (i.e., the shock becomes larger), in order to take advantage of a good state, both firms decide to reduce their dividend distributions and to invest more. If the shock becomes large enough, firms save precautionarily. Because issuing equity is costly, firms save internal resources to avoid equity issues in the near future; that is, they seek a reduction in their external financing costs. If the shock is very large, it becomes optimal to stop saving and to issue equity to finance a larger investment. In the latter case, both firms have similar investment policies, but the firm with less cash has to issue more costly equity and invest slightly less compared to the firm with larger cash holdings. The difference in equity issuance is exactly equal to the cash balance differential multiplied by $1+\kappa$ (i.e. 1+ equity issuance cost). To summarize, the three panels show that cash-rich firms have a larger amount of internal resources that allows them to (i) distribute more dividends when they are financially unconstrained, (ii) invest more and save more when financing constraints are binding, and (iii) reduce their financing cost when they decide to invest in excess of their internal resources, everything else being equal.

Capital is an endogenous state variable because of capital adjustment costs. The bottom panels of Figure 10 show the policies for two firms that only differ in their beginning-of-period capital stock (i.e., size). The patterns of the investment and financing policies are very similar to the ones in the top panels. What emerges from these patterns is the importance of precautionary financing for small firms. The bottom panels show that large firms have a smaller precautionary savings motive because they rely on larger expected cash flows, and for this reason they need to retain less cash when financing constraints are binding. Conversely, small firms engage in larger precautionary savings, and in doing so they deliver a larger cash-to-assets ratio given (i) their larger amount of savings and (ii) their smaller beginning-of-the-period capital.

Simulation

We simulate a panel of 40,000 firms for 300 periods to let the economy settle in the ergodic state. At each time t, a fraction λ of firms exits the economy. These firms are replaced by an equal mass of entrants in each period. We discard the first 100 periods and calibrate the model using the remaining 200.

To run our experiments, we start from the stationary distribution and simulate our economy for an additional 35 years. We repeat the simulation 200 times and report average values across the 200 simulations.

B Supplemental Empirical Results

In this appendix, we provide graphs and tables to supplement the empirical analysis in the main body of the paper. All figures and tables are at the end of the document.

The secular increase in cash. Figure 11 shows the average cash–to–assets ratio for U.S. public companies over the period 1958–2013. What has been dubbed as *the secular increase* (Bates et al. (2009)) starts in 1979. In the period 1979–2013, the average cash-holdings value goes from 0.08 in 1979 to 0.25 in 2013.

Which Cohorts Drove up the Cash–to–Assets Ratio? Given the persistence of cash balances documented in Table 3, we follow Brown and Kapadia (2007) and estimate a model that includes a cohort fixed effect using firms that become public from 1959 onward. The results are reported in Table 9.

When we include cohort fixed effects, the positive trend in column I becomes not significant. In column II, the estimates of the cohort fixed effects are differences from the excluded cohort (1974–1978), whose estimated value is given by the intercept. Column II makes clear that no differences exist in cohort fixed effects prior to the 1979-1983 cohort, whereas starting with the latter cohort, the fixed effect becomes significantly bigger and its evolution mimics the evolution of the average cash holdings at entry depicted in Figure 1. In columns III and IV, we separately estimate cohort fixed effects for R&D–intensive and non–R&D–intensive firms. In both cases, no significant differences exist in cohort fixed effects among the first four cohorts, thus supporting the evidence in Figure 2 that places the beginning of the secular increase in cash holdings with the 1979–1983 cohort.

By contrast, starting with the excluded cohort, the cohort fixed effects are always significantly different from the excluded cohort (the intercept) for the R&D–intensive sector. In addition, starting with the 1984-1988 cohort and up to 1999-2003 cohort the fixed effect becomes significantly larger (i.e., the difference in the fixed effect between two successive cohorts is positive and significantly different from zero).

On the other hand, the cohort fixed effects for the non–R&D–intensive sector (column

II) are significantly different from the 1974-1978 cohort only for the 1999–2003 cohort.[30] Differently from the R&D–intensive sector, only the 1984-1988 cohort fixed effect (significantly smaller) and 1999–2003 cohort fixed effect (significantly larger) are statistically different from the 1979-1983 cohort fixed effect. In addition, the magnitude of the cohort fixed effects is always much smaller for the non–R&D–intensive sector, furthering the evidence of a minor role played by this sector in determining the secular increase in cash holdings.

Cash decomposition: Selection effect versus within effect. Table 10 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.[31] The average cash holdings equal 0.082 in 1979 and 0.237 in 2012, an increase of 0.152. 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 -0.192, whereas the overall contribution of the *selection effect* is 0.343.

Cash decomposition: Value-weighted results. Table 11 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

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

[30] During the first half of the 2000s, two events had a significant impact on corporate cash holdings: the Sarbanes–Oxley Act and the 2003 dividend tax cut. Bargeron et al. (2010) document a significant increase in cash holdings following the introduction of the Sarbanes–Oxley Act. Officer (2011) documents a large increase in cash holdings in anticipation of the dividend tax cut.

[31] Table 11 below shows the results are even robust to value-weighted cash ratios.

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. However, it is enough to eliminate the top 1% of the size distribution from the sample to make the selection effect due to R&D–intensive entrants the most important driving force. When we eliminate firms in the top 5% of the size distribution, we moreover obtain the negative within-effect results, consistent with the equally weighted approach.

Cash decomposition: R&D–intensive versus non-R&D–intensive firms. Table 8 reports the evolution of the average cash-to-assets ratio for R&D–intensive and non-R&D–intensive firms over the period 1979–2013. For each firm category, we separate between firms that have entered the Compustat database within five years and firms that have been in the Compustat database for more than five years.

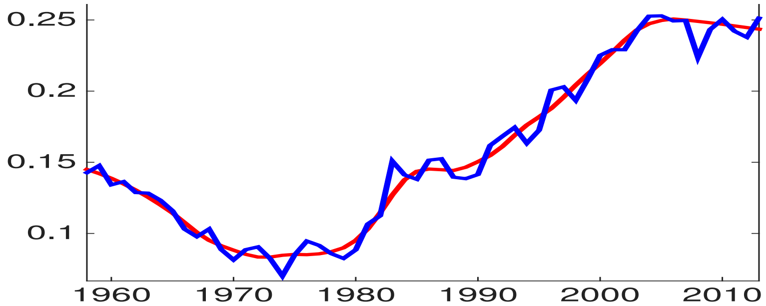
The exit margin. Figure 12 compares the average cash holdings of entering and exiting firms in our sample. The data show that exitors hold almost the same cash ratio as the average firm over time, supporting the assumption of an exogenous and i.i.d. exit process used in the model.

Post-entry dynamics. What happens to cash holdings in the subsequent years after entry? Figure 13 shows the differences in basic firm characteristics at entry (cash, R&D, tangibility, and net leverage) persist over time. That is, high R&D firms' characteristics do not converge to the levels held by low R&D firms.

The figure shows cash holdings for entrants from the entry year (year 0) up to five years after entry (year 5) together with other key firm-level characteristics. Both high R&D–intensive and low-R&D–intensive firms deplete their cash holdings after the entry year. The difference in average cash holdings between the two set of firms decreases during the first two years after entry and then stays constant around 0.18. The R&D activity for R&D–intensive firms stays constant during the five years after entry and fluctuates around 0.11, whereas low-R&D firms' post-entry R&D investment fluctuates around 0.5% of total assets.

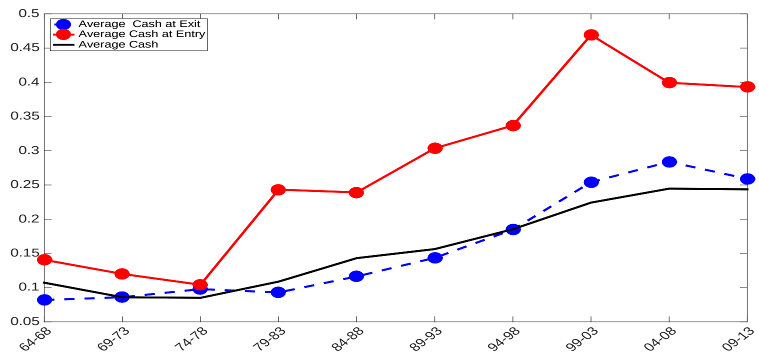
Both categories of firms show an increase in their post-entry values for tangibility and net leverage. However, these values are highly persistent and the difference at the entry stage remains stable for the entire post-entry period. In short, R&D–intensive and non-R&D–intensive firms do not converge in terms of key firm characteristics linked to production and financing structure. This evidence supports our modeling decision of having a fixed type of firms rather than assuming firms that can dynamically change their type.

Figure 11: Average cash–to–assets ratio of U.S. listed firms



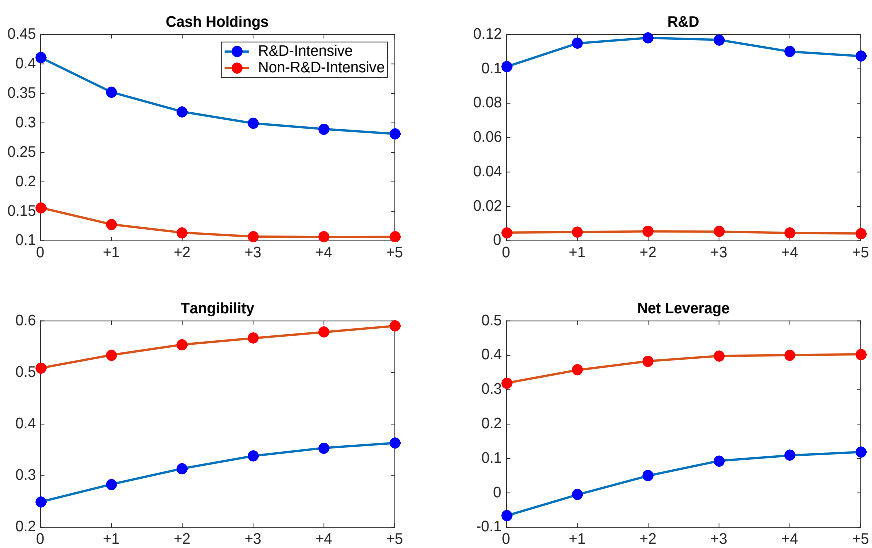
This figure reports the average cash–to–assets ratio of U.S. public companies over the period 1958-2013.

Figure 12: Average cash–to–assets ratio at entry and at exit of U.S. 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.

Figure 13: Dynamic Evolution Post-entry



The figure reports the average value from entry (year 0) up to five years after entry (year 5) of the following firm-level characteristics: cash holdings, R&D expenditure, long-term debt, tangibility, leverage, and net leverage. The red line refers to non-R&D–intensive firms, whereas the blue line refers to R&D–intensive firms.

Table 8: Average Cash Ratios

	IPO within last 5 years		No IPO within last 5 years	
Year	R&D	Non R&D	R&D	Non R&D
1979	10.56%	9.48%	7.85%	7.86%
1980	14.38%	12.52%	7.96%	7.84%
1981	20.22%	15.05%	9.04%	8.22%
1982	21.62%	13.60%	9.33%	8.89%
1983	30.87%	16.85%	12.23%	10.28%
1984	27.62%	15.19%	11.49%	9.34%
1985	25.67%	13.61%	11.52%	9.54%
1986	27.95%	15.43%	12.67%	9.98%
1987	29.54%	13.43%	13.05%	10.35%
1988	25.72%	12.54%	12.71%	9.23%
1989	24.38%	11.28%	13.33%	9.54%
1990	26.23%	10.37%	14.02%	9.22%
1991	32.73%	11.86%	15.10%	9.70%
1992	34.25%	12.28%	16.70%	9.36%
1993	36.52%	11.79%	17.09%	9.39%
1994	33.63%	9.79%	16.90%	8.25%
1995	35.46%	9.88%	16.94%	7.82%
1996	38.90%	11.73%	18.80%	8.15%
1997	37.66%	11.20%	20.07%	8.58%
1998	36.06%	11.05%	20.00%	8.10%
1999	40.07%	10.88%	20.78%	7.49%
2000	40.76%	11.62%	23.08%	7.21%
2001	41.60%	12.61%	24.82%	8.11%
2002	41.02%	15.06%	27.37%	8.82%
2003	43.64%	17.47%	29.51%	10.15%
2004	45.40%	19.10%	29.78%	11.04%
2005	45.95%	15.38%	30.59%	11.42%
2006	43.77%	13.51%	31.18%	11.40%
2007	42.99%	12.40%	31.05%	10.90%
2008	40.52%	11.25%	27.69%	10.26%
2009	39.66%	12.93%	30.34%	12.65%
2010	38.54%	12.22%	31.18%	13.29%
2011	36.62%	11.86%	30.46%	12.05%
2012	35.65%	9.40%	29.93%	11.40%
2013	32.77%	10.09%	29.87%	11.38%
Difference 1979-2013	22.20%	0.61%	22.02%	3.53%

The sample includes U.S. incorporated Compustat firm-year observations from 1979-2013 with at least five years of observations, positive values for assets and sales, excluding utilities and financial firms. A firm's IPO year is the first year for which a stock price (prcc_f) is observed. This IPO assignment is consistent with Jay Ritter's dataset. We also sort firms into the R&D versus non-R&D sector, where R&D sectors are those with more than 2% of R&D expenditures relative to assets.

Table 9: Estimating the Entry Cohort Effect

	Pooled OLS I	All Firms II	Non-R&D Intensive III	R&D Intensive IV
t	0.415***	-0.000	-0.033*	0.017
	(0.019)	(0.019)	(0.019)	(0.032)
1959-1963	(Column III)	-1.521*	-0.931	-1.811
		(0.916)	(1.103)	(1.499)
1964-1968		-1.335	-0.322	-2.274
		(0.921)	(1.148)	(1.407)
1969-1973		-0.932	-1.130	0.705
		(0.840)	(0.952)	(1.473)
1979-1983		6.288***	2.445**	8.547***
		(0.980)	(1.113)	(1.519)
1984-1988		7.970***	1.263	13.711***
		(1.000)	(0.993)	(1.602)
1989-1993		10.739***	0.527	19.177***
		(1.053)	(1.004)	(1.608)
1994-1998		13.513***	2.183**	22.126***
		(1.043)	(1.074)	(1.560)
1999-2003		23.835***	7.186***	29.465***
		(1.299)	(1.562)	(1.705)
2004-2008		16.569***	2.678**	28.328***
		(1.513)	(1.326)	(2.222)
2008-2013		14.255***	3.667	22.919***
		(3.805)	(2.606)	(5.731)
Constant	11.678***	11.349***	10.270***	13.022***
	(0.342)	(0.719)	(0.817)	(1.210)
Observations	76,872	76,872	38,553	38,319
R-squared	0.031	0.108	0.016	0.163

We estimate the following baseline linear equation:

$$CH_{i,t} = \alpha + \beta t + \varepsilon_{i,t}$$

The dependent variable is the cash–to–assets ratio defined as Compustat item CHE divided by Compustat item AT an expressed in percentage terms.The sample includes Compustat firm-year observations from 1979-2013 with at least five years of observations, positive values for assets and sales, excluding financial firms (SIC codes 6000 to 6999) and utilities (SIC codes 4000 to 4999). Differently from the regression in Table 3, we exclude firms that entered Compustat before 1959. In column I, we run pooled OLS regressions and we normalize the year 1979 to zero. In column II, we report the results with cohort fixed effects. In column III, we report the results with cohort fixed effects only for the R&D–intensive sector, whereas in column IV, we report the results with cohort fixed effects only for the non–R&D–intensive sector. We report standard errors that are clustered at the firm level. * denotes significance at the 10% level, ** denotes significance at the 5% level, and *** denotes significance at the 1% level.

Table 10: 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	0.083
1980	0.000	0.004	0.002	0.006	-0.006	0.007	0.002	0.002	0.088
1981	0.003	0.011	0.004	0.018	-0.003	0.018	0.006	0.021	0.107
1982	-0.002	0.006	0.001	0.006	-0.004	0.024	0.007	0.027	0.112
1983	0.012	0.019	0.008	0.038	0.007	0.043	0.015	0.065	0.151
1984	-0.026	0.014	0.002	-0.010	-0.019	0.057	0.018	0.055	0.141
1985	-0.011	0.005	0.003	-0.003	-0.029	0.062	0.021	0.053	0.138
1986	-0.003	0.013	0.005	0.014	-0.033	0.075	0.025	0.067	0.151
1987	-0.013	0.010	0.004	0.001	-0.046	0.085	0.029	0.068	0.153
1988	-0.018	0.004	0.002	-0.012	-0.063	0.088	0.031	0.056	0.139
1989	-0.002	0.003	-0.001	0.001	-0.065	0.092	0.030	0.056	0.138
1990	-0.009	0.011	0.001	0.003	-0.074	0.102	0.032	0.060	0.141
1991	-0.003	0.019	0.004	0.020	-0.077	0.121	0.036	0.080	0.162
1992	-0.019	0.020	0.005	0.006	-0.096	0.141	0.041	0.086	0.168
1993	-0.021	0.022	0.006	0.006	-0.118	0.163	0.047	0.092	0.174
1994	-0.027	0.012	0.005	-0.011	-0.145	0.175	0.052	0.081	0.163
1995	-0.017	0.020	0.004	0.007	-0.162	0.195	0.056	0.088	0.172
1996	-0.012	0.033	0.007	0.028	-0.174	0.228	0.063	0.116	0.201
1997	-0.014	0.012	0.004	0.003	-0.188	0.240	0.067	0.119	0.203
1998	-0.011	0.002	0.000	-0.009	-0.199	0.242	0.067	0.110	0.193
1999	-0.007	0.022	0.001	0.016	-0.206	0.263	0.068	0.126	0.208
2000	-0.007	0.023	0.000	0.017	-0.213	0.287	0.069	0.142	0.225
2001	0.012	-0.006	-0.002	0.004	-0.201	0.281	0.067	0.146	0.229
2002	0.008	-0.007	-0.001	0.001	-0.192	0.274	0.066	0.147	0.230
2003	0.020	-0.006	-0.001	0.013	-0.173	0.268	0.065	0.160	0.242
2004	0.000	0.008	0.002	0.010	-0.172	0.276	0.066	0.170	0.252
2005	0.000	0.000	0.001	0.000	-0.173	0.276	0.067	0.170	0.253
2006	-0.006	0.000	0.001	-0.005	-0.179	0.275	0.068	0.165	0.249
2007	-0.003	0.004	0.000	0.000	-0.182	0.279	0.068	0.165	0.249
2008	-0.015	-0.010	-0.001	-0.026	-0.197	0.269	0.067	0.139	0.224
2009	0.027	-0.008	0.000	0.019	-0.170	0.261	0.067	0.158	0.243
2010	0.008	0.001	-0.002	0.007	-0.162	0.262	0.065	0.165	0.250
2011	-0.007	0.000	-0.002	-0.009	-0.170	0.262	0.063	0.156	0.242
2012	-0.008	0.005	-0.002	-0.005	-0.178	0.267	0.062	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 11: 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 firm in the top 1% of the size distribution, and (iii) excluding firm 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.