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WHY WAIT? A CENTURY OF LIFE BEFORE IPO

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ABSTRACT

Firms that entered the stock market in the 1990s were younger than any earlier cohort since World War I. Surprisingly, however, firms that IPO'd at the close of the 19th century were just as young as the companies that are entering today. We argue here that the electrification-era and the IT-era firms came in young because the technologies that they brought in were too productive to be kept out very long. The model assumes that the stage before IPO is a learning period during which the firm refines the idea before committing to it at the IPO stage. The better the idea, the higher is the opportunity cost of a delay in its implementation, and the earlier the firm will have its IPO.

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Why Wait? A Century of Life Before IPO

By Boyan Jovanovic and Peter L. Rousseau*

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Over the past century the U.S. financial system has grown and become more efficient. Does that mean that ideas are being commercialized faster than before? Apparently not. Using three separate concepts of age, Figure 1 shows that companies that first listed at the close of the 19th century were as young as the companies that are entering the NYSE, AMEX and NASDAQ today. We argue here that the electricity-era and the information-technology (IT) era firms came in younger because the technologies that they brought in were too productive to be kept out very long. The model that we use to explain this resembles Edward C. Prescott and Michael Visscher's (1980) model of the absorption of personnel, and Jovanovic and Yaw Nyarko's (1996) model of learning about a production function.

The figure shows HP-filtered average waiting times from founding, from first product or process innovation, and from incorporation to exchange listing. It is based upon individual company histories and our extension of the CRSP database from its 1925 starting date back through 1885 using newspaper sources. The appendix describes the data and methods. Table 1 shows the coverage by decade. Table 2 shows pre-listing events for some of the better-known companies in our sample. Even here, the average waiting time to listing is 30 years from founding, 15 years from first innovation, and 14 years from incorporation. The waits have clearly shortened, however, for more recent high-tech entrants.

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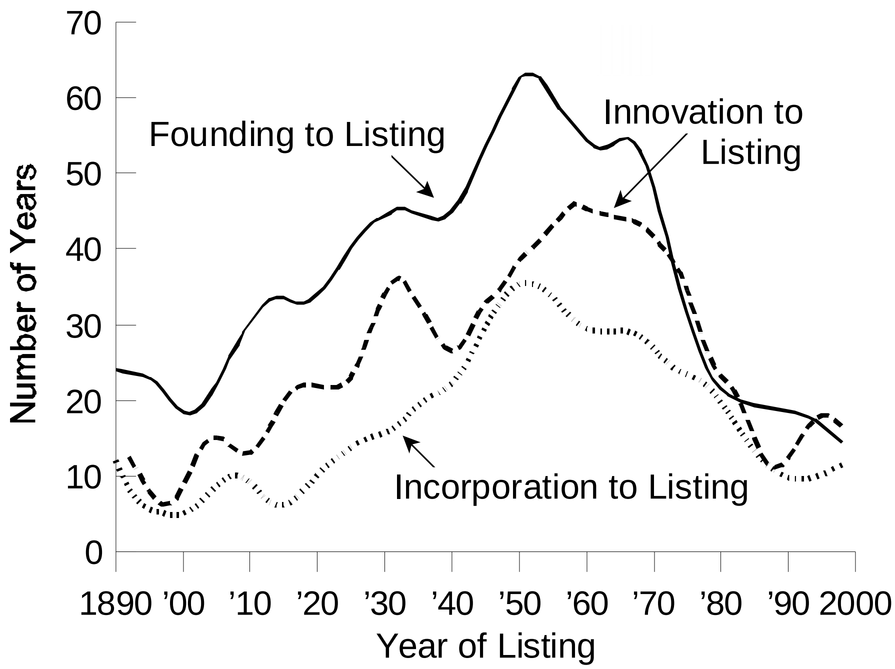


Figure 1: Waiting Times to Exchange Listing.

Table 1–Number of Firms in the Waiting-Time Sample

Decade	All New Listings	Included Incorps	Included Foundings	Included 1st Innovs
1890's	112	52	41	5
1900's	112	78	44	10
1910's	214	190	97	14
1920's	545	492	273	43
1930's	231	197	78	26
1940's	271	246	97	28
1950's	254	241	78	36
1960's	2,008	964	198	94
1970's	4,517	1,405	262	74
1980's	6,322	904	790	90
1990's	6,930	1,469	1,869	62
Totals	21,516	6,238	3,827	482

Sources: see appendix.

Table 2
Key Dates in Selected Company Histories

Company name	Founding date	1st major product or process innovation	Incorporation date	IPO date	Nyse/Nasdaq Listing date
General Electric	1878	1880	1892	1892	1892
A T & T	1885	1892	1885	1901	1901
Detroit Edison	1886	1904	1903	1909	1909
General Motors	1908	1912	1908	1917	1917
Coca Cola	1886	1893	1919	1919	1919
Pacific Gas & Electic	1879	1879	1905	1919	1919
Burroughs/Unisys	1886	1886	1886	1924	1924
Caterpillar	1869	1904	1925	1929	1929
Kimberly-Clark	1872	1914	1880	1929	1929
Proctor & Gamble	1837	1879	1890	1929	1929
Bristol-Myers Squibb	1887	1903	1887	1929	1933
Boeing	1916	1917	1916	1934	1934
Pfizer	1849	1944	1942	1942	1944
Merck	1891	1944	1934	1946	1946
Disney	1923	1929	1940	1940	1957
Hewlett Packard	1938	1938	1947	1957	1961
Time Warner	1922	1942	1922	1964	1964
McDonalds	1948	1955	1965	1965	1966
Intel	1968	1971	1969	1972	1972
Compaq	1982	1982	1982	1983	1983
Micron	1978	1982	1978	1984	1984
Microsoft	1975	1980	1981	1986	1986
America Online	1985	1988	1985	1992	1992
Amazon	1994	1995	1994	1997	1997
E-Bay	1995	1995	1996	1998	1998

Data from *Hoover's Online*, Kelley (1954), and company websites.

The first major products or innovations for the firms listed in the table are: GE 1880, Edison patents incandescent light bulb; AT&T 1892, completes phone line from New York to Chicago; DTE 1904, increases Detroit's electric capacity six-fold with new facilities; GM 1912, electric self-starter; Coca Cola 1893, patents soft-drink formula; PG&E 1879, first electric utility; Burroughs/Unisys 1886, first adding machine; CAT 1904, gas driven tractor; Kimberly-Clark 1914, celu-cotton, a cotton substitute used in WWI; P&G 1879, Ivory soap; Bristol-Myers Squibb 1903, Sal Hepatica, a laxative mineral salt; Boeing 1917, designs Model C seaplane; Pfizer 1944, deep tank fermentation to mass produce penicillin; Merck 1944, cortisone (first steroid); Disney 1929, cartoon with soundtrack; HP 1938, audio oscillator; Time-Warner 1942, "Casablanca"; McDonalds 1955, fast food franchising begins; Intel 1971, 4004 microprocessor (8088 microprocessor in 1978); Microsoft 1980, develops DOS; Compaq 1982, portable IBM-compatible computer; Micron 1982, computer "eye" camera; AOL 1988, "PC-Link"; Amazon 1995, first online bookstore; E-Bay 1995, first online auction house.

I. A model of the waiting-time to an IPO

Figure 1 shows that the firm has its first innovation soon after founding, but that it then takes years, even decades to list on a stock exchange. We shall interpret this delay as a period during which the firm and possibly its lenders learn about what thefirm's optimal investment is; at the end of this period, an initial public offering (IPO) leads to an influx of capital that enables the firm to implement its idea. Delaying the IPO defers the date when revenues start to come in, but this may still raise the firm's net present value because investment is irreversible and information can help the firm avoid a costly mistake. In this sense the information is an intangible investment that raises the firm's efficiency.

Now, pharmaceuticals are, perhaps, the only business in which one can so sharply separate the information gathering stage from the production stage, and even there, the IPO does not coincide exactly with the start of production. Elsewhere, learning and production take place more or less simultaneously; the firms starts small, it learns a little, adds capacity, learns a little more, adds more capacity, changes its product a little, finds new suppliers, invests and hires a few more people, then learns a little more, and the process goes on. The firm defines itself by the investments that it makes, and loses flexibility gradually. Here we assume that *all* investment occurs at the IPO date, and that only then does the firm start to generate revenue.

The production function is

$$y_t = A - (\theta - x)^2 . \tag{1}$$

Here y is output, A is the known quality of the technology, θ is an unknown parameter, and x is a decision like the setting of a dial. The firm needs k units of capital to produce, and, like x, this investment is made at date $T > 0$ and is irreversible. We think of x as describing the choice of product, process, inputs, and so on, and we think of k as the cost of creating capacity, of advertising and the like.

Before investing, the firm learns about θ by observing signals

$$ds_t = \theta dt + \sigma_\varepsilon d\varepsilon_t \quad \text{for } t \in [0, T], \tag{2}$$

where ε_t is Brownian motion. The cost of observing the signals is c per unit of time. Firms differ in θ, which is distributed normally with mean $\bar{\theta}$ and variance σ_θ^2. A firm does not know its own θ and the normal distribution is its prior over θ. After t periods of signals generated by (2), the posterior variance $\sigma_t^2 \equiv E_t\left(\theta - E_t\left(\theta\right)\right)^2$ is

$$\sigma_t^2 = \left(\frac{1}{\sigma_\theta^2} + \frac{t}{\sigma_\varepsilon^2}\right)^{-1}. \tag{3}$$

The firm must decide whether to enter and, if it does, when to invest (T) and what x to choose. We take these decisions up in reverse order.

Choosing x: Once set, x cannot be changed, and from date T on, the firm's output will be constant. The firm cannot declare bankruptcy no matter how large a mistake $|x - \theta|$ it has made and, so, if it is risk-neutral, it will choose x to maximize the expected discounted value of its output, $r^{-1}E_T\left(y\right)$, for which the optimal decision is

$$x = E_T\left(\theta\right). \tag{4}$$

Substituting from (4) into (1), the expected lifetime value of the project as of date t, net of investment costs, is

$$\frac{1}{r}E_t\left(y\right) - k = \frac{1}{r}\left(A - \sigma_t^2\right) - k. \tag{5}$$

The delay-to-invest serves to accumulate information capital, the value of which is $r^{-1}\left(\sigma_\theta^2 - \sigma_t^2\right)$.

Choosing T: Normalize the founding date to zero. The optimization problem is

$$v\left(A\right) \equiv \max_{T \geq 0}\left\{e^{-rT}\left[\frac{1}{r}E_t\left(y\right) - k\right] - \int_0^T e^{-rt}cdt\right\}. \tag{6}$$

The optimal T will not depend on the realized signals because the expression for σ_t^2 in (3), and hence $E_t\left(y\right)$, depends only on t, and not on the signals. At an interior optimum, the firm equates the gains to waiting on the left-hand side of (7) to the sum of the foregone earnings $\left(A - \sigma_t^2 - rk\right)$ and observation costs:

$$-\frac{1}{r}\frac{\partial \sigma_t^2}{\partial t} = A - \sigma_t^2 - rk + c. \tag{7}$$

Substitution from (3) into (7) for σ_t^2 leads to the optimal waiting time

$$T^* = -\frac{\sigma_\varepsilon^2}{\sigma_\theta^2} + \frac{2}{r}\left(\sqrt{\left[1 + 4\frac{\left(A + c - rk\right)}{r\sigma_\varepsilon^2}\right]} - 1\right)^{-1}, \tag{8}$$

which decreases with c and A (the direct and indirect cost of sampling) and increases with σ_θ^2 (the ignorance that sampling serves to wipe out) and k (the resources committed). It also decreases with r when r is small, and increases with σ_ε^2 when σ_ε^2 is small. Indeed, as $\sigma_\varepsilon^2 \to 0$, $T^* \to 0$. Finally, for the firm to want to wait in the first place, it is enough that $\sigma_\theta^2 > 2(A - rk + c)$.

Entry: Firms for which $v(A) > 0$ enter. The marginal entrant, A^*, has $v(A) = 0$. Assume that

$$A = zu, \tag{9}$$

where z is an aggregate shock, and u is project-specific and distributed $F(u)$. The number of entrants is $1 - F(A^*/z)$, so that z raises entry.

Market-book ratios: If the pre-IPO costs are on the books, the zero-profit condition implies that the market-book ratio for the marginal firm is unity. A higher z raises the number of inframarginal firms and the market-book ratio of the group as a whole.

II. Explaining the inverted-U shape for T

The parameters z, σ_θ^2, and k are about technology, whereas c and σ_ε^2 are also about the financial system. Can we guess how they have evolved? Electricity (1890-1930) and the microcomputer (1971-) were technologies as widespread in their effects as was steam. One would guess that they gave rise to higher z's than did the middle of the 20th century which was the era of the technology-refining incumbent. Since new technology is unfamiliar, σ_θ^2 was probably high in 1890 and 1971, and declined thereafter. Physical capital matters less today than it used to, and k has probably declined. Since c most likely reflects the foregone earnings of the founder and his financiers, it has probably gone up, and σ_ε^2 has probably declined since it reflects the evaluative expertise of the people managing the project in its infancy.

We shall first consider an explanation based on z alone, then point to its shortcomings, and finally ask if other parameters may have varied in a way that would remedy things. An explanation based on z is that when great projects arrive, firms will be more impatient to implement them, and they will list sooner. Three side implications of such an explanation are, first, that market-book ratios should have been higher in those two eras than in the middle of the century, second, that the smaller T should have led to more mistakes by some firms which, when combined with some

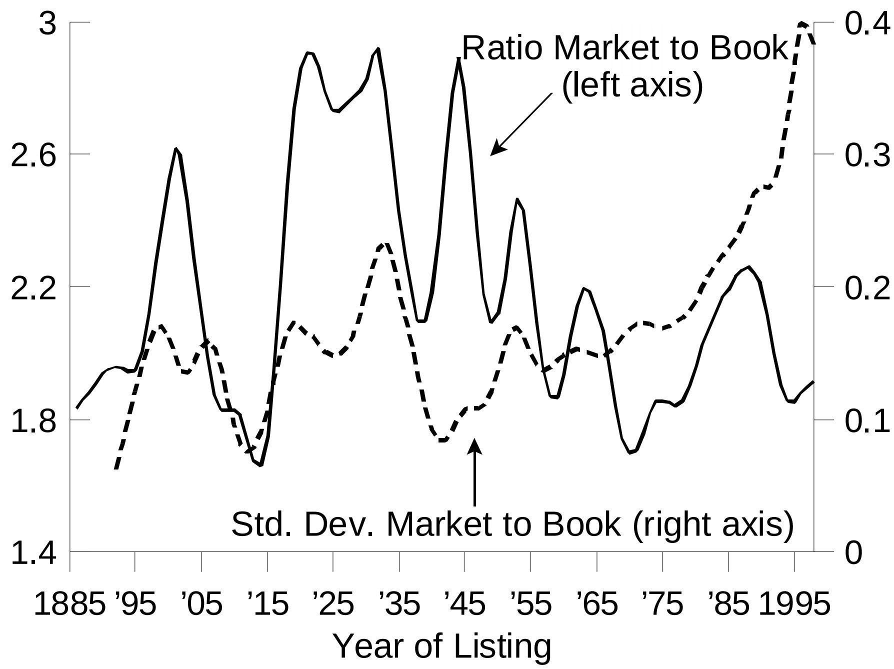
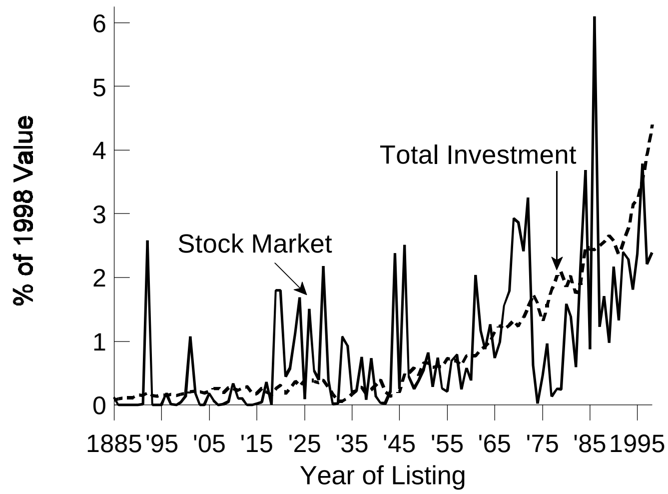


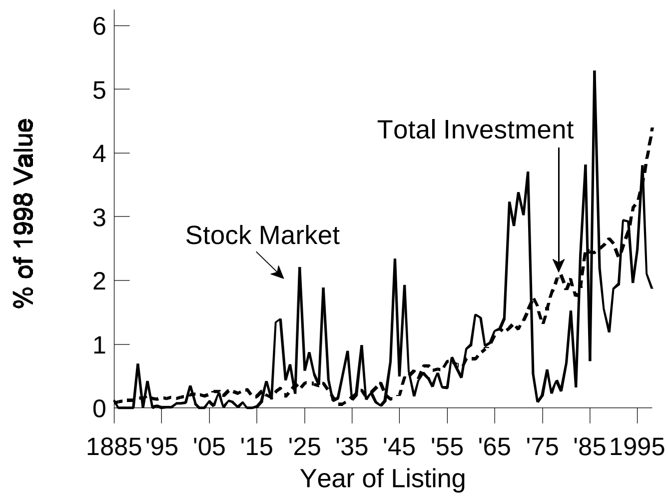
Figure 2: Market to Book Ratios for 1998 Compustat Firms.

lucky guesses by other firms should have led to a greater dispersion of market-to-book values for the electricity and the IT cohorts, and, third, that the rate of entry should be higher in the two cohorts. Figure 2 accounts for the ratio of market to book value in 1998 by year of exchange listing for the 6,494 Compustat firms that coincide with our extended CRSP sample. The numerator of the ratio includes equity capital and long-term debt, and the data are adjusted for mergers within the sample. As the model predicts, market-to-book values are, for the most part, higher for the electricity and IT cohorts. The figure also shows the within-cohort variance of these ratios as a proxy for the variance of $|x - \theta|$ within the cohorts. Except for having different trends, the two series look similar, and the correlation between the detrended series is 0.23.

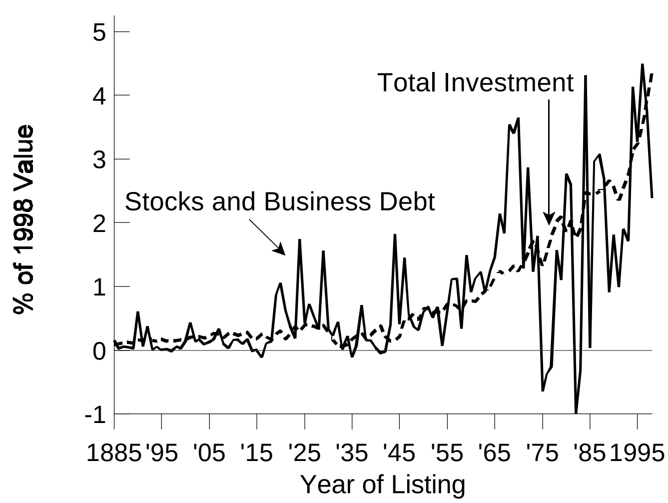
The series in Figure 2 are based on the Compustat sample which does not include all firms listed on the NYSE, AMEX and NASDAQ. To consider a wider sample, Figure 3 shows the percent of 1998 market capitalization in our extended CRSP database attributable to each entry year. The dashed line in each panel accounts for



(a) unadjusted



(b) adjusted for mergers



(c) adjusted for mergers and net debt issuance

FIGURE 3. VINTAGE COMPOSITION OF STOCKS, BUSINESS DEBT, AND INVESTMENT IN 1998

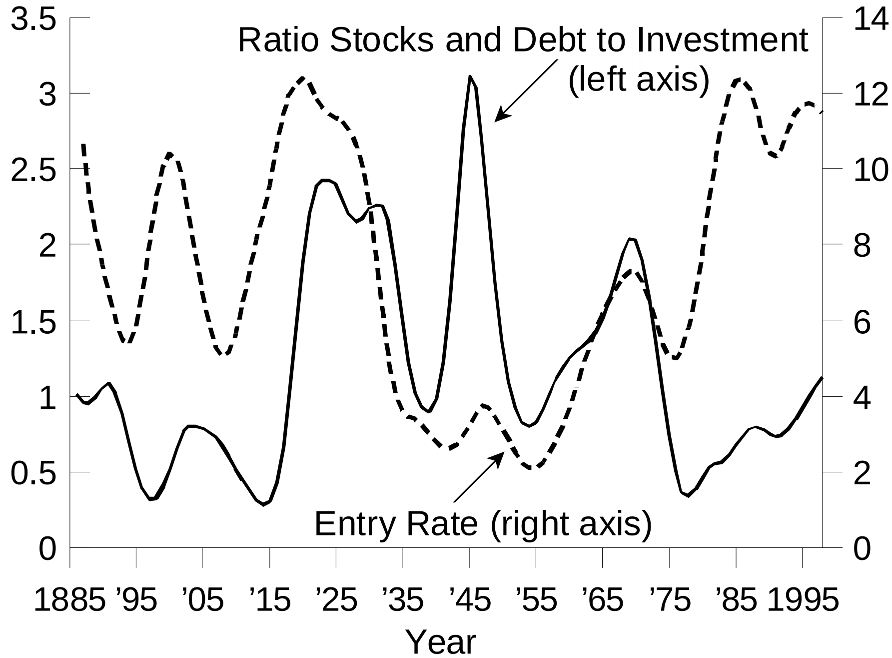


Figure 4: Market Value to Investment Ratios by Vintage and Firm Entry Rates.

total real investment by the vintage of that investment. In Panel (a), we use wait times from incorporation to listing to smooth out spikes in 1962 and 1972 that would coincide with the additions of AMEX and NASDAQ firms to CRSP. Panel (b) adjusts the figure for 5,422 mergers among listed firms, while Panel (c) adds real net debt issuance to the solid line. The appendix describes these adjustments.

The solid line in Figure 4 is the ratio of surviving entry value to investment. The electricity cohorts appear to have created value in today's market that far exceeds investment at the time of their entry, though this is not the case for the IT cohort. The dashed line, however, which is the percentage of entrants among the firms in each year, shows vigorous entry for both the electricity and IT cohorts, and this confirms the $z-$ based explanation.

Now to some refinements of this explanation. The market-to-book values are high during the electrification and IT eras, but the highest values occur in the 20's and in the mid–late '80s, that is, in the second half of each technological episode. Like σ_θ^2, z is probably highest at the start of a new technological era and then, as the best projects are taken up, it probably declines, but so does σ_θ^2. If the decline in the latter dominates the decline in z, perhaps one can explain the high performance 20 years or more into the diffusion process. To say more about this, one needs a model in which z and σ_θ^2 are endogenous.

Suppose that as electricity and IT aged, the best projects were indeed taken up, and that the respective z's fell. This would explain why T rose in the early part of the 20th century, but it would not be consistent with the continuous decline in T after the mid-1970's. To explain this decline one may point to the rapid development of financial institutions and the rise of the venture capital industry. A rise in c or a fall in σ_ε^2 may explain part of the decline in T since the 1970's, and this line of thinking could be explored further. Finally, the probable decline in k may have contributed to the recent decline in T.

Appendix: data and methods

Figure 1, Table 1, Table 2: For 1925-98, listing years are those for which firms enter CRSP. For 1885-1924, they are years in which prices first appear in the NYSE listings of *The Annalist, Bradstreet's*, *The Commercial and Financial Chronicle*, or *The New York Times*. The combined database defines our sample of 21,516 firms. The 6,238 incorporations in Figure 1 are from *Moody's Industrial Manual* (1920, 1928, 1955, 1980), Standard and Poor's *Stock Market Encyclopedia* (1981, 1988, 2000), and various editions of Standard and Poor's *Stock Reports*. The 3,827 foundings are from Dun and Bradstreet's *Million Dollar Directory* (2000), Moody's, Etna M. Kelley (1954), and individual company websites. The 482 first innovations were obtained by reading company histories in *Hoover's Online* (2000) and company websites. We linearly interpolate the series between missing points and HP-filter before plotting.

Figure 2: Book and market values in 1998 for individual firms are from Compustat. Market value is constructed as book value (item 6) less nominal value of common stock (item 85) plus market value of common stock (the product of items 24 and 25) and long-term debt (item 9). This implies that preferred stocks enter at their nominal values. Listing years are from our extended CRSP database. We compute the variance of the market-to-book ratios for any year with two or more surviving entrants. We again interpolate between missing points and HP-filter.

Figure 3: Private domestic investment is from Kendrick (1961) for 1885-1953, and from the National Income and Product Accounts thereafter. AMEX firms enter CRSP in 1962 and NASDAQ firms in 1972. Since NASDAQ firms traded over-the-counter before 1972 and AMEX's predecessor (the New York Curb Exchange) dates back to at least 1908, we adjust the capitalizations in Panel (a) for spikes in 1962 and 1972 by re-assigning the capital to an approximation of the "true" entry years. We do this by using Standard and Poor's *Stock Report* and *Stock Market Encyclopedia* to obtain incorporation years for 117 of the 274 surviving NASDAQ firms that entered CRSP in 1972 and for 907 of the 5,213 firms that entered NASDAQ thereafter. We then use the sample distribution of differences between incorporation and listing years of the post-1972 entrants to assign the capital of the 1972 entrants into proper "IPO" years. 13.4% of the surviving 1998 capital can be attributed to 1972 entrants, but not all entered CRSP via NASDAQ. We therefore assume that the average percentage of 1998 capital attributed to the years 1969-1971 (1.7%) entered CRSP in 1972 through NYSE or AMEX, leaving the difference of 11.7% to re-distribute. We use a similar procedure for the 1962 AMEX entrants.

The merger adjustment in Panel (b), as well as that in Figure 2, draws upon several sources. CRSP itself identifies 7,455 firms that exit by merger between 1926 and 1998, but links only 3,488 of them to acquirers. Using the *Directory of Obsolete Securities* and *Predicasts F&S Index of Corporate Change,* however, we found acquirers for 3,646 (91.9%) of the unlinked mergers, of which 1,803 were in CRSP. We also examined mergers for 1895-1930 in the manufacturing and mining sectors from worksheets underlying Ralph L. Nelson (1959), and for 1885-94 from the financial news in weekly issues of the *Commercial and Financial Chronicle.* We then recursively traced the merger history of every 1998 CRSP firm and its targets, apportioning the 1998 capital of the survivor to its own entry year and those of its merger partners using the share of combined value attributable to each in the year before the merger.

Panel (c) adjusts for the annual change in U.S. business debt, defined as the market value of corporate bonds and commercial and industrial bank loans For 1945-98, book values are from the *Flow of Funds* (Table L.4 lines 5 and 6). For 1885-1944, the book value of outstanding corporate bonds is from W. Braddock Hickman (1952), and that of bank loans is from *All Bank Statistics* and the *Historical Statistics* *of the United States.* Since the last two sources report June 30 figures, we average across years for consistency with the calendar-year basis of the *Flow of Funds.* After ratio-splicing these components into a continuous series, we convert to market values using the average annual yields on Moody's AAA-rated corporate bonds for 1919-98 and Hickman's "high grade" bond yields, which line up precisely with Moody's, for 1900-18. We use yields on "high-grade industrial bonds" from Milton Friedman and Anna J. Schwartz (1982) for 1885-99. To determine market value, we let r_t be the bond interest rate and compute the weighted average

$$r_t^* = \frac{1}{\sum_{i=1885}^{t} (1-\delta)^{t-i}} \sum_{i=1885}^{t} (1-\delta)^{t-i} r_{t-i}.$$

We choose $\delta = 10\%$ to approximate the growth of new debt plus retirements of old debt, and multiply the book value of outstanding debt by the ratio $\frac{r_t^*}{r_t}$ to obtain its market value.

Figure 4: The solid line is the ratio of surviving entry value to investment in Panel (c) of Figure 3. The numbers of entrants and listed firms depicted by the dashed line are from our extended CRSP database. We HP-filter both series before plotting.

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