The Q-Theory of IPOs

Boyan Jovanovic and Peter L. Rousseau*

October 12, 2003

Abstract

We find that new firms' real investment responds much more elastically to aggregate Tobin's Q than does that of established firms. On the financial side, IPOs respond more elastically to Tobin's Q than seasoned offerings of securities. The explanation seems to be that a high aggregate Q raises *new* firms' desired investment much more than it raises the desired investment of *incumbents*. For the period from 1955 to 2001, the Q-elasticity of IPOs is about 1.2, and the elasticity of new-firms' investment is about 0.7. These are about 20 times more than is usual in Q regressions. On the other hand, the Q-elasticity of seasoned offerings is actually negative (-0.05), and the elasticity of incumbents' investment is 0.04. Though not statistically significant, the average of these estimates is even smaller than is usual.

1 Introduction

A firm's initial public offering on the stock market – its "IPO" – represents a transfer of ownership of the firm and its assets into the hands of the public, at least in part. At the same time an IPO also augments the funds available to the firm thereby enabling the firm to invest more. Thus an IPO plays the dual role of (i) reallocating ownership of existing assets and (ii) enabling the acquisition of new assets (Choe, Masulis and Nanda 1993, Lowry 2002, Moskowitz and Vissing-Jorgensen 2002).

If one purpose of an IPO is to raise investment funds, then perhaps neoclassical investment theory – Q theory – can explain some aspects of the behavior of IPOs. That is the aim of this paper. If it is to explain IPOs, however, Q-theory must also explain why IPOs respond to Q more elastically than aggregate investment does, a fact that emerges from Figure 1. The solid line shows the de-trended ratio of the value of new stock-market listings to gross private domestic investment. The dashed line is the de-trended ratio of stock market capitalization (MCAP) to gross

*NYU and the University of Chicago, and Vanderbilt University. We thank J. Campbell and P. Veronesi for comments and the NSF for support.

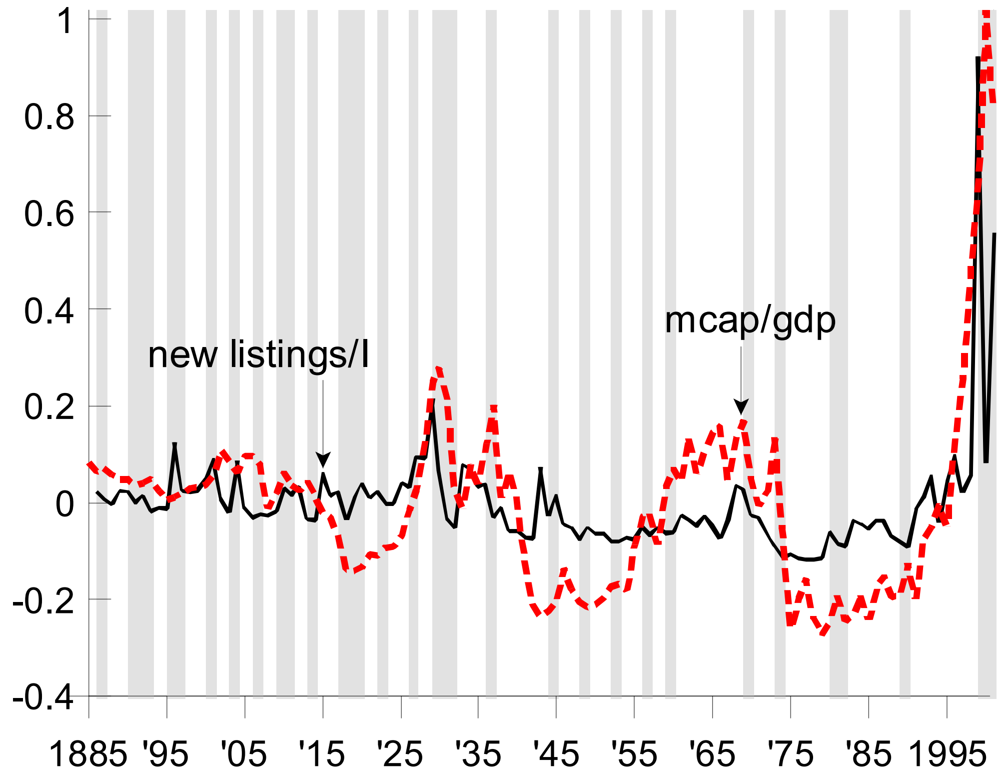


Figure 1: De-trended new stock-market listings relative to gross private domestic investment and de-trended stock market capitalization relative to GDP, 1886-2001.

domestic product (GDP), which is highly correlated with Q (our de-trended micro-based estimates of Q from 1955 to 2001 have a correlation coefficient of 0.79 with de-trended MCAP/GDP). Business cycle recessions as dated by the National Bureau of Economic Research (NBER) are shaded.[1] The value of new equity listings was largest in the decade surrounding 1900, around 1915, the late 1920's, at the end of the Second World War, in the late 1960s, the mid-1980s, and throughout the 1990s.

[1]The stock market data are from the University of Chicago's Center for Research in Securities Prices (CRSP) files for 1925-2001. NYSE firms are available in CRSP continuously, AMEX firms after 1961, and NASDAQ firms after 1971. We extended the CRSP stock files backward from their 1925 starting year by collecting year-end observations from 1885 to 1925 for all common stocks traded on the NYSE. Jovanovic and Rousseau (2001a, p. 1-2) describe these data in detail. New listings are given by the total year-end market value of firms that entered our extended CRSP database in each year, excluding American Depository Receipts (ADR's). Gross private domestic investment in current dollars is from the Bureau of Economic Analysis (2002, Table 1, pp. 123-4) for 1929-2001, to which we ratio splice the gross capital formation series in current dollars, excluding military expenditures, from Kuznets (1961b, Tables T-8 and T-8a) for 1885-1929. GDP is from the Bureau of Economic Analysis (2002, table 1, pp. 123-24) for 1929-2001, Kendrick (1961, table A-IIb, cols. 4 and 11, pp. 296-97) for 1889-1929, and Berry (1988, table 9, pp. 25-26) for 1885-1889.

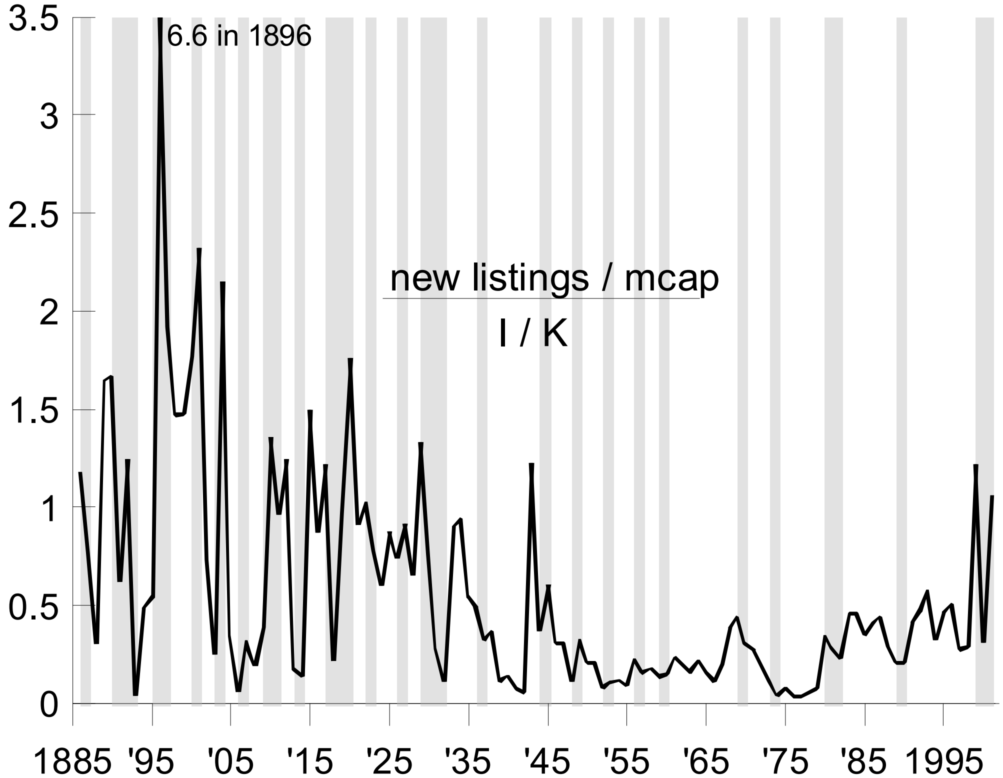


Figure 2: The ratio of new listings to stock market capitalization relative to the ratio of private domestic investment to GDP, 1886-2001.

This wave-like activity is also highly correlated with MCAP/GDP, as evidenced by a correlation coefficient of 0.62 for the de-trended series.

Figure 2 shows the ratio of new stock-market listings to market capitalization relative to the investment rate.[2] The same entry waves appear here as in Figure 1, but the rate of entering capital to the market is even larger in the first half of the 20th century using this measure.

Empirical findings.—Real investment waves are less dramatic than IPO waves.[3]

[2] We construct the net capital stock using the private fixed assets tables of the Bureau of Economic Analysis (2002) for 1925-2001. Then, using the estimates of the net stock of non-military capital from Kuznets (1961a, Table 3, pp. 64-5) in 1869, 1879, 1889, 1909, 1919, and 1929 as benchmarks, we use the percent changes in a synthetic series for the capital stock formed by starting with the 1869 Kuznets (1961a) estimate of $27 billion and adding net capital formation in each year through 1929 from Kuznets (1961b) to create an annual series that runs through the benchmark points. Finally, we ratio-splice the resulting series for 1886-1925 to the later BEA series.

[3] This is probably because IPOs and seasoned issues entail high fixed costs, as does issuing corporate bonds and bank loans (Lee *et al.* 1996). Firms therefore finance their real investments out of retained earnings.

This is mainly because IPOs raise capital for new firms, and new firms have on average accounted for only 8.1 percent of real investment from 1886 to 2001. "Seasoned" issues of shares by incumbent firms are imperfectly correlated with IPOs, with a correlation coefficient of 0.75. New capital (real and financial expansions of new firms) is more pro-cyclical than incumbent capital: New capital responds far more to movements in (aggregate) Tobin's Q.[4] Incumbent real capital responds to Q hardly at all.

About the model.—The evidence seems to fit a "putty-clay" type of view that assembling an operation from scratch is cheaper than adding to existing operations piecemeal.[5] This is an "Ak" growth model in which capital is homogeneous but in which there are two ways of adding to it: via incumbent firms, and via new firms. The two modes of investment entail different adjustment costs. We assume that IPOs are the means by which new firms finance their investments. Our model expresses a modified putty-clay hypothesis in terms of adjustment costs: These costs are flatter for entering firms than for incumbents, and this explains (or at least accounts for) the more elastic response of entering capital to variations in Q. The model also has growth implications. A lower cost of entering capital raises the long-run growth rate of the economy. This makes the model potentially interesting for understanding how growth is linked to finance.

Literature.—In several papers, Ritter (1984), e.g., documents facts about IPOs. Using partial equilibrium models, Jovanovic and Rousseau (2001b) and Pastor and Veronesi (2003) try to explain IPOs via fundamentals.

2 Model

Let K denote a firm's capital stock. This is the only input in production which means that we are not distinguishing physical from human capital. The firm's output is

$$\text{output} = z_1 K. \tag{1}$$

The firm's investment is X and its capital stock follows the law of motion

$$K' = (1-\delta)\, K + X. \tag{2}$$

Adjustment costs.—There are two adjustment costs: one for entrants, and one for incumbents. An incumbent's adjustment cost is

$$C(x)\, K, \quad \text{where } x = \frac{X}{K}, \tag{3}$$

[4] This finding is not new. Boddy and Gort (1971) find that the fraction of investment going to new plants rises in booms. DeJong and Ingram (2001) find that young people leave school earlier in booms.

[5] Cummins and Dey (1998), Gort and Lee (2002), and Gandal, Kende & Rob (1997) offer empirical support for the putty clay view. Recent models with putty-clay elements are Campbell (1998), Gilchrist and Williams (2000), Greenwood and Jovanovic (1999) and Yorukoglu (1998).

whereas an entrant's adjustment cost is

$$C^* (x) K.$$

Shocks.—There are two shocks in the model. The first, z_1, is the common multiplicative shock to each firm's production function (1). The second, z_2, is a common shock to the creative margin of the economy which we shall describe later. The shocks follow the Markov process

$$\Pr \{z_{t+1} \leq z' \mid z_t = z\} = F(z', z). \tag{4}$$

We shall be more explicit about this process later.

Valuation of risky income streams.—The pair $(z_1, z_2) \equiv z$ affects aggregate consumption and, hence, the marginal utility of consumption and, hence, today's value of next-period's consumption. As is customary in asset pricing models, imagine a state-contingent price of consumption next period to be $p(z, z')$.[6]

3 The investment decision

Incumbents.—The price of capital is unity. The firm's capital stock is given, and so maximizing total value is the same as maximizing value per unit of capital. Because returns to scale are constant, this value does not depend on the firm's size. Its profit per unit of capital is $z - C(x) - x$. An incumbent's market value per unit of capital is

$$Q(z) = \max_{x \geq 0} \{z - C(x) - x + (1 - \delta + x) Q^* (z)\}, \tag{5}$$

where

$$Q^* (z) = \int p(z, z') Q(z') dF(z'; z) \tag{6}$$

is the discounted expected unit value of capital in the next period. The first-order condition for the incumbent's investment rate, x, is

$$C'(x) = Q^* (z) - 1. \tag{7}$$

Entrants.—We normalize the firm's pre-entry level of capital at K_0.[7] This is the capital that the firm's founder has (e.g., in his garage) before taking the firm public.[8]

[6] It is given in (10) below and derived in Appendix 1. The economywide states will be the triple (z_1, z_2, K), but K will not affect the marginal rate of substitution between consumption in adjacent periods.

[7] Campbell (1998) assumes that a firm's initial size is exogenously fixed, and this is exactly what we do here. This allows us to talk about the entrant's adjustment costs on the same footing as those of incumbents.

[8] We analyze the pre-IPO period in Jovanovic and Rousseau (2001b), and so do Pastor and Veronesi (2003).

Assume that K_0 does not produce output at all. Let Y denote the investment of an entering firm and let

$$y = \frac{Y}{K_0}.$$

Then y solves the equation

$$\max_{y \geq 0} \left\{ -C^* \left(y \right) - y + \left(1 - \delta + y \right) Q^* \left(z \right) \right\} \tag{8}$$

so that the first-order condition is

$$C^{*\prime} \left(y \right) = Q^* \left(z \right) - 1. \tag{9}$$

Preferences.—Preferences are

$$E_0 \sum_{t=0}^{\infty} \beta^t U \left(c_t \right).$$

We assume they are homothetic, which means that K will not affect the marginal rate of substitution between consumption at different dates, so that

$$\beta \frac{U' \left(c' \right)}{U' \left(c \right)} = p \left(z, z' \right), \tag{10}$$

which we have used in (6). The household's savings problem and the associated equilibrium condition linking savings to investment is discussed in Appendix 1.

The birth process for new firms.—A firm owes its existence to an idea that defines it. Let n be the number of new firms and the number of new ideas. Suppose that n is proportional to the stock of capital:[9]

$$n = z_2 K. \tag{11}$$

This means that the total investment of entering firms is

$$n y K_0 = \left(z_2 K \right) y K_0,$$

and the total adjustment costs are

$$n C^* \left(y \right) K_0 = \left(z_2 K \right) C^* \left(y \right) K_0.$$

We shall assume that z_2 is Markovian too and independent of z_1 conditional on their past. That is, if $F^1 \left(\cdot \right)$ and $F^2 \left(\cdot \right)$ are the transition functions, in (4) we have

$$F \left(z', z \right) = F^1 \left(z_1', z_1 \right) F^2 \left(z_2', z_2 \right).$$

[9] Of course K derives its origin from existing ideas so that n depends, indirectly, on all previous n's. Therefore ideas build on previous ideas, roughly as in Romer (1990). When accumulating K, firms do not take into account its productivity in generating new ideas n. Therefore, equilibrium will *not* solve the planning problem, and growth will be slower than optimal.

4 Equilibrium

Because returns to K are constant, the distribution of capital among incumbents does not matter. Only its total amount, K does. Let c be consumption. The resource constraint is

$$\frac{c}{K} = z_1 - x - z_2 y K_0 - C(x) - z_2 C^*(y) K_0$$

and the law of motion for the capital stock reads

$$K' = (1 - \delta + x + z_2 y K_0) K.$$

The two investment rates x and y solve (7) and (9). These latter two equations contain Q^*, which is defined in (5) and (6). Finally, (10) must hold. This guarantees that savings will equal investment. This part of the equilibrium is developed in Appendix 1, leading up to (24).

The equilibrium is not optimal. A partial result in Appendix 2 shows that at least for states z in which $x(z) > \delta$, equilibrium growth is too low relative to the social optimum. That is a sufficient condition, and the converse is not necessarily true.

5 Example

Let $\gamma > 1$ and let $\mu > 1$. Assume that

$$C(x) = x^\gamma, \text{ and } C^*(y) = y^\mu.$$

Then the first-order conditions read

$$\gamma x^{\gamma-1} = Q^* - 1,$$

and

$$\mu y^{\mu-1} = Q^* - 1.$$

Rearranging, the two conditions reduce to

$$x = \frac{1}{\gamma}(Q^* - 1)^{1/(\gamma-1)} \tag{12}$$

and

$$y = \frac{1}{\mu}(Q^* - 1)^{1/(\mu-1)}. \tag{13}$$

We shall produce evidence that γ is much higher than μ.

The number of IPOs.—The effect of Q^* on y is not matched by an effect on the number of IPOs, n. From (5) we see that Q is not related to K which means from (11) that Q will not affect n either. Any relation between n and Q in the model will emerge only through the effect that z_2 may have on on K' and on the equilibrium interest rate, and, hence, on Q^*. We don't have the result in general, but when z is constant, equations (14) and (19) imply that the relation is negative across steady states. A further test of the model, then, is that Q and the number of IPOs, n, should be negatively correlated.

6 Empirics

To estimate (12) and (13), we will work with three measures of x and y, two ways of measuring Q^*, and two partially overlapping time periods.

6.1 Regressions with firm-level data

In the first set of regressions, we measure x as the sum of total changes in the year-end gross capital stock among incumbents in the Compustat database divided by the sum of their net capital stocks. We denote this measure of x by x_{real}. It is thus a value-weighted average of X/K in the model. For y, we use the average year-end real net capital stock of firms that entered the CRSP database in each year.[10] We denote this measure by y_{real}. This method assumes that the firm accumulates all of its initial capital at the time of IPO.[11] Since y in the model is normalized by the firm's pre-IPO capital stock, K_0, and we do not have data on these stocks, we assume them to be constant across firms and over time in building y_{real} and in the subsequent empirical work. Our data cover the period from 1955 to 2001, which corresponds to the period for which we can compute a continuous series for average Q using Compustat. Since the liquidity of the capital market is often considered a key determinant of firm-level investment, we also estimate specifications that include the ex-post inflation-adjusted rate of return on three-month commercial paper.

Figure 3 shows x_{real} and y_{real} with recessions as dated by the National Bureau of Economic Research (NBER) shaded. IPOs fall during four of the seven NBER recessions, and all three since 1980, but behave countercyclically in the 1956-57 and

[10] The gross and net capital stocks are Compustat data items 7 and 8 respectively. An IPO is dated by the year that a firm enters the CRSP database, but we include its net capital stock (from Compustat) in our series for y_{real} only if the firm joins Compustat in the same year. We do this because the firm coverage of Compustat expanded as balance sheet data became available for particular firms, and this does not necessarily correspond to the year of IPO. Since CRSP includes all firms listed on the NYSE, the AMEX after 1962, and NASDAQ after 1972, the correspondence between entry year and IPO is reliable for all years other than 1962 and 1972, when existing AMEX and NASDAQ firms entered CRSP en masse. The 1962 and 1972 values in Figure 3 are for this reason interpolated, and are excluded from the regression analysis. We also exclude ADRs, which are indirect listings of large foreign firms through U.S. banks. Since most ADRs either were listed previously in other countries or from countries where a formal IPO was not possible, their inclusion would distort our analysis of the factors that influence the listing behavior of U.S. firms.

[11] Moskowitz and Vissing-Jorgensen (2002) report this figure at closer to 30 percent.

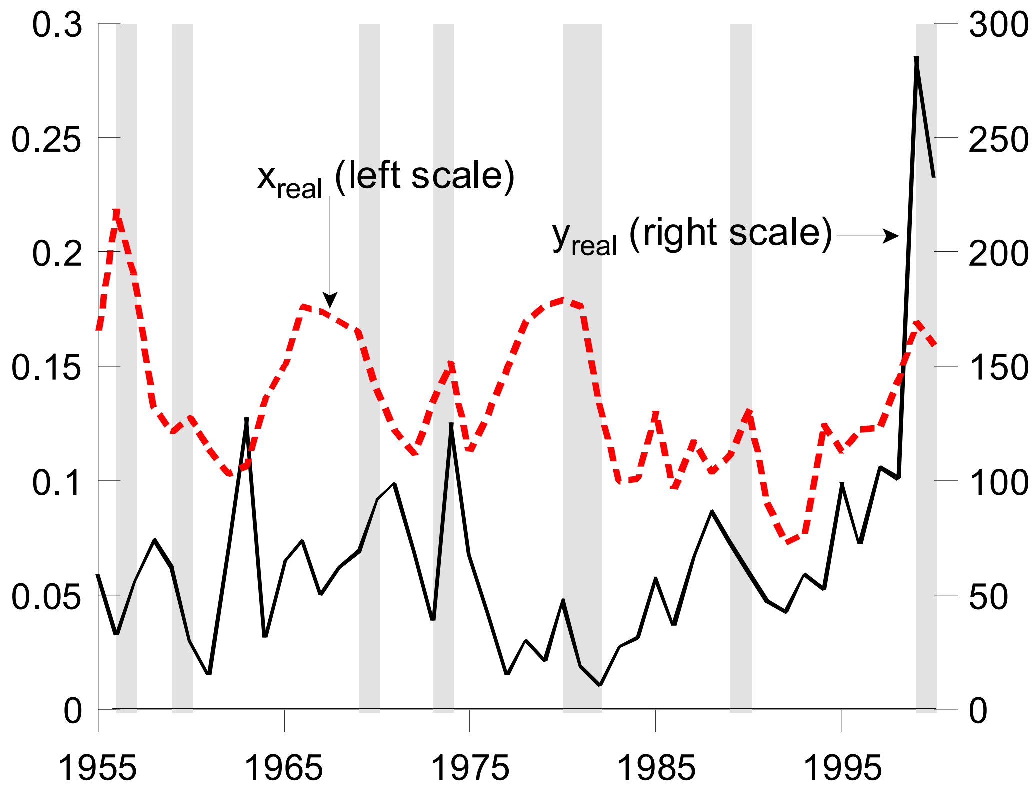


Figure 3: Gross investment per incumbent as a share of net capital, x_{real}, and average entering capital of IPOs, y_{real}, in millions of 2001 dollars, 1955-2001.

1969-70 recessions. If anything, incumbent investment seems to lead investment by new firms, with the highest cross-correlation between series of 0.124 obtaining for $(y_{\text{real},t},\ x_{\text{real},t-1})$.

Figure 4 shows the Tobin's Q proxied by average market-to-book ratios from Compustat after adjusting book values for inflation.[12] We represent Q^*, or the continuation value of Q in (6), with the one-year lag of this series.[13]

Table 1 shows the regressions, which include a linear time trend. The left panel shows that the average investment of newly-listed firms is sensitive to $Q^* - 1$, and

[12] In our model a firm's average Q is the same as its market-to-book ratio, but the two may in fact diverge significantly due to the effects of changing tax rates on market values and depreciation on book values. Since these adjustments would affect firms and investors differently and over time, we prefer to derive market-to-book ratios directly from our micro-based balance sheet data.

[13] To compute market values using Compustat, we start with common equity at current share prices (the product of items 24 and 25) and add in the book value of preferred stock (item 130) and short- and long-term debts (items 34 and 9). Book values are computed similarly, but with the book value of common equity (item 60) rather than market value. We omit observations with market-to-book ratios in excess of 100, since most are likely to be data errors.

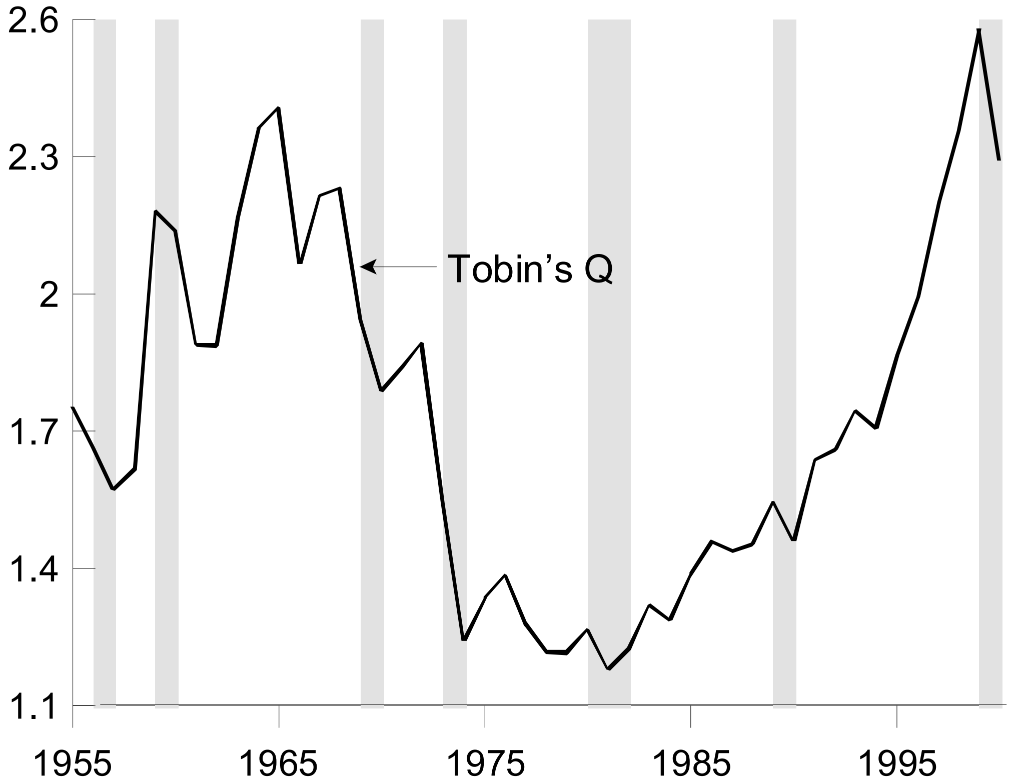


Figure 4: Tobin's Q as proxied by average market-to-book ratios, 1955-2001.

Table 1. Regressions of the Average Investment of New Listings (y_{real}) and Incumbents (x_{real}) on Q^*, 1955-2001.

	Dependent variable			
	$\ln(y_{\text{real}})$	$\ln(y_{\text{real}})$	$\ln(x_{\text{real}})$	$\ln(x_{\text{real}})$
$\ln(Q^* - 1)$	0.668	0.637	0.042	0.044
	(4.87)	(4.63)	(0.76)	(0.77)
r_t		-0.063		0.004
		(-1.37)		(0.19)
trend	0.021	0.025	-0.006	-0.006
	(3.38)	(3.67)	(-2.37)	(-2.19)
constant	3.827	3.871	-1.857	-1.859
	(20.80)	(20.94)	(-25.15)	(-24.51)
R^2	.441	.466	.138	.139
N	44	44	44	44

Note: t-statistics are in parentheses.

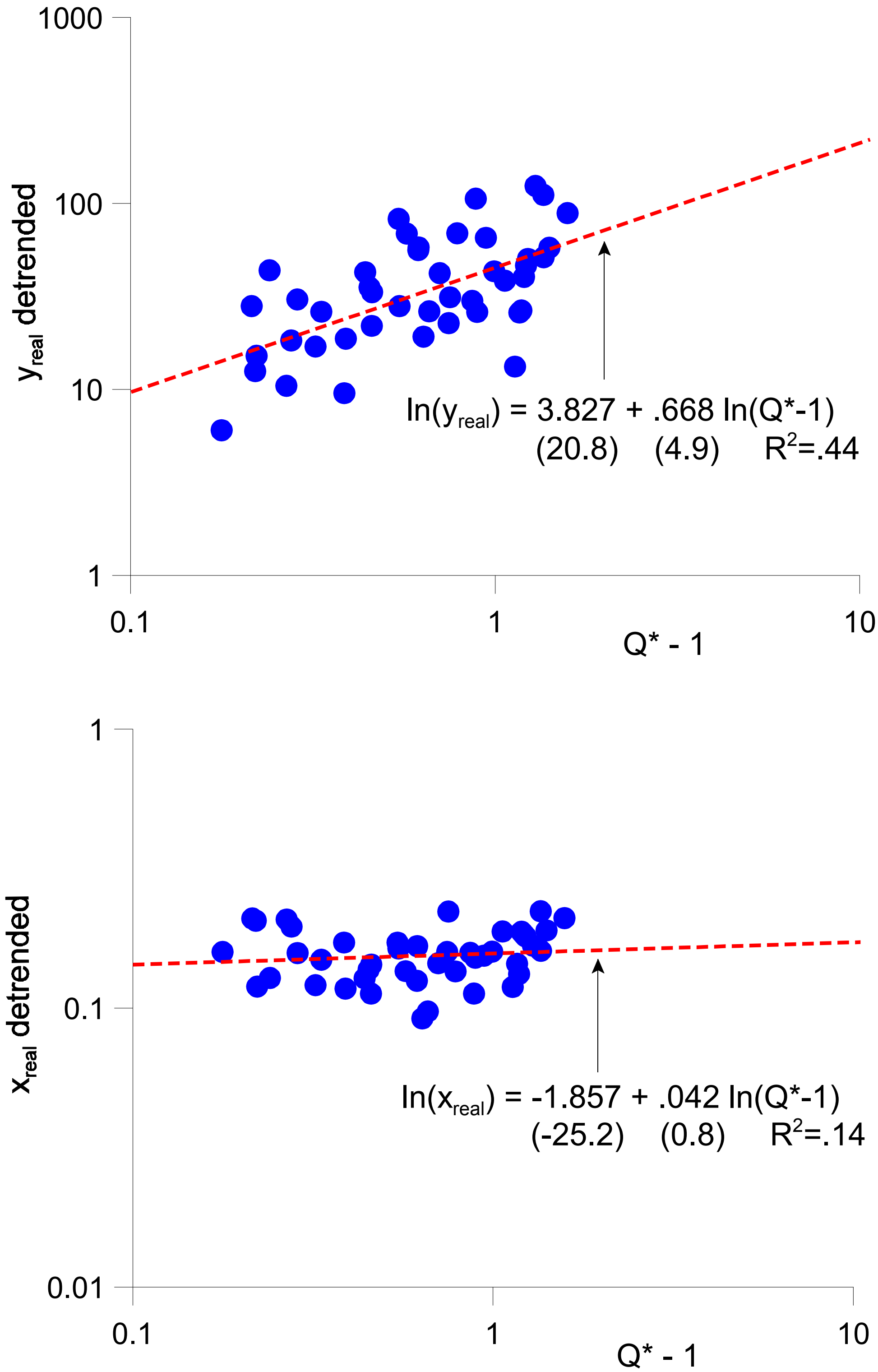


Figure 5. Scatterplots of regressions of the average investment of new stock market listings (y_{real}) and incumbents (x_{real}) on Tobin's Q, 1955-2001.

that this relationship is statistically significant at the 1 percent level. This implies that firms tend to float larger IPOs when Q is high than when it is lower. In the right panel, the coefficients on Q^*-1 are not statistically significant, suggesting that the Q is not an important determinant of growth in the capital stock among going concerns. Further, the liquidity of the capital market, as measured by the commercial paper rate (r_t), has a coefficient in the y_{real} regression which, while not statistically significant, is negative with a t-statistic that does exceed unity. This is consistent with larger IPOs occurring when interest rates are low. The coefficient on r_t is positive but very small and not statistically significant in the x_{real} regression.

Figure 5 contains scatterplots of the regressions reported in Table 1 that exclude the commercial paper rate. We use the estimated coefficients on the linear trend terms to de-trend y_{real} and x_{real} before plotting them against $Q^* - 1$.

6.2 Regressions with financial aggregates Y/K and X/K

In this section we measure y as the total real value of IPOs in each year and x as the total value of seasoned offerings (SEO's), both as percentages of the net stock of private capital in the United States.[14] We denote these variables by y_{fin} and x_{fin}. Since $n = z_2 K$, if z_2 were a constant rather than a random variable, normalization of IPO volumes by either n (to get averages) or K (to obtain ratios) would both be consistent with the theory. Figure 6 show the series for x_{fin} and y_{fin}, once again with NBER recessions shaded. Dashed lines denote interpolations between missing values Over this longer period, IPOs fall during 8 of 12 recessions, while seasoned offerings fall during only 6 of them.

6.2.1 Using Q's from Compustat

Table 2 presents our findings for 1955-2001. Figure 7 shows scatterplots of the regressions. Similarly to our findings with the average sizes of new entrants and the growth of incumbents' capital, the log of IPO volume as a percentage of total capital responds positively to the log of $Q^* - 1$ at the one percent level, while $Q^* - 1$ is not a statistically significant determinant of seasoned offerings. When we add the real commercial paper to the specifications, it is positive and significant in the IPO regression but not statistically significant in the SEO regression. This finding reflects the tendency for interest rates to rise as the business cycle matures, and for firms to delay their IPOs hoping to time the market.

[14] IPO volumes are gross proceeds from Ritter (2003, Table 5, p. 6) for 1975-2001, to which we ratio-splice the year-end market value of common equity for firms that entered the CRSP database in each year from 1927-1974. Ritter's data are from the database made available by the Securities Data Corporation. Seasoned offerings are proceeds for U.S. equity issues from 1927-2001 (using data underlying Baker and Wurgler (2000), who collected it from various issues of the *Federal Reserve Bulletin*) less IPOs as defined above. We deflate IPOs and seasoned offerings using the implicit price deflator for GDP.

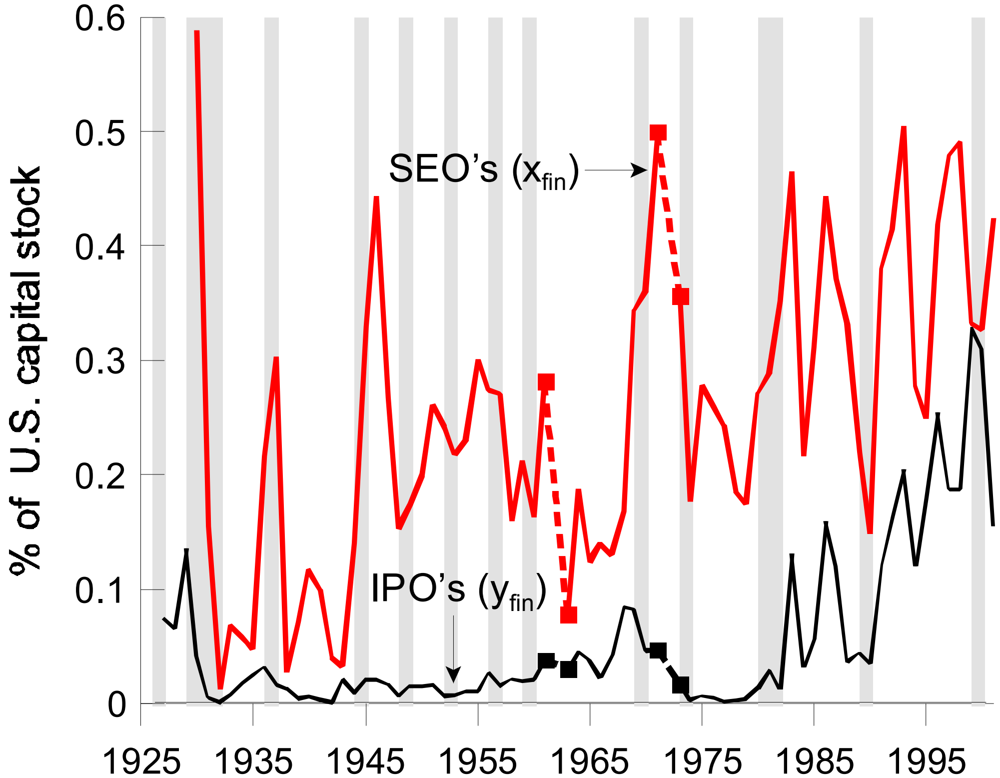
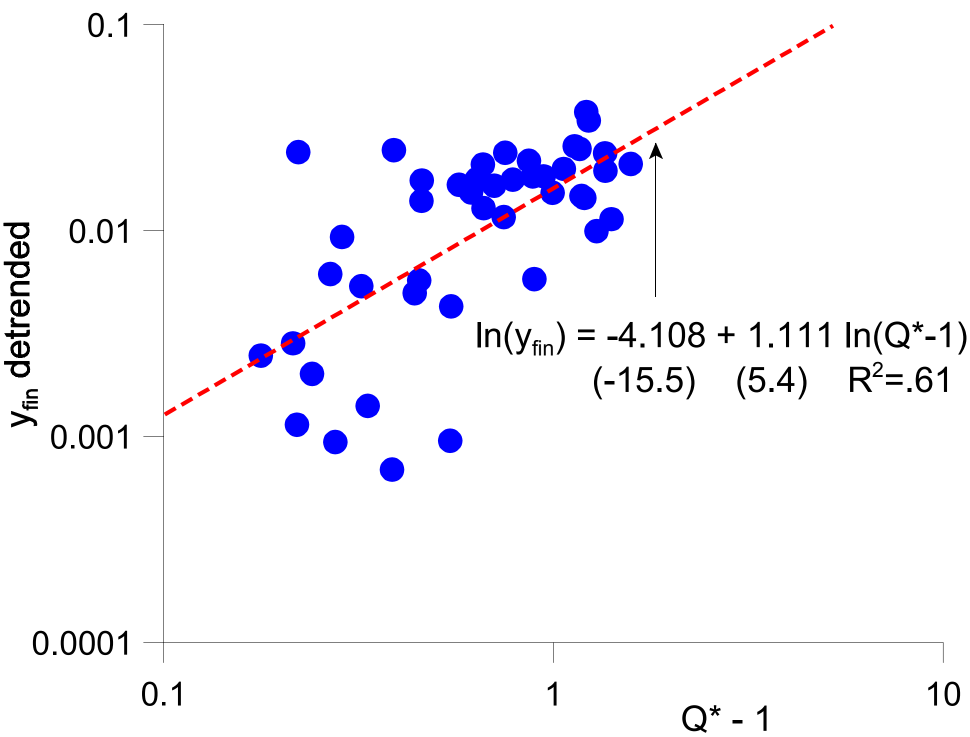


Figure 6: IPO's and SEO's as percentages of the total U.S. capital stock, 1927-2001.

Table 2. Regressions of IPO (y_{fin}) and SEO (x_{fin}) volume as percentages of the U.S. capital stock on Q^*, 1955-2001.

	Dependent variable			
	$\ln(y_{fin})$	$\ln(y_{fin})$	$\ln(x_{fin})$	$\ln(x_{fin})$
$\ln(Q^*-1)$	1.111	1.211	-0.033	-0.045
	(5.42)	(6.44)	(-0.36)	(-0.48)
r_t		0.206		-0.025
		(3.21)		(-0.76)
trend	0.059	0.045	0.016	0.018
	(6.43)	(4.88)	(3.96)	(3.85)
constant	-4.108	-4.251	-1.738	-1.721
	(-15.48)	(-17.41)	(-14.36)	(-13.91)
R^2	.606	.685	.278	.288
N	45	45	45	45

Note: t-statistics are in parentheses.



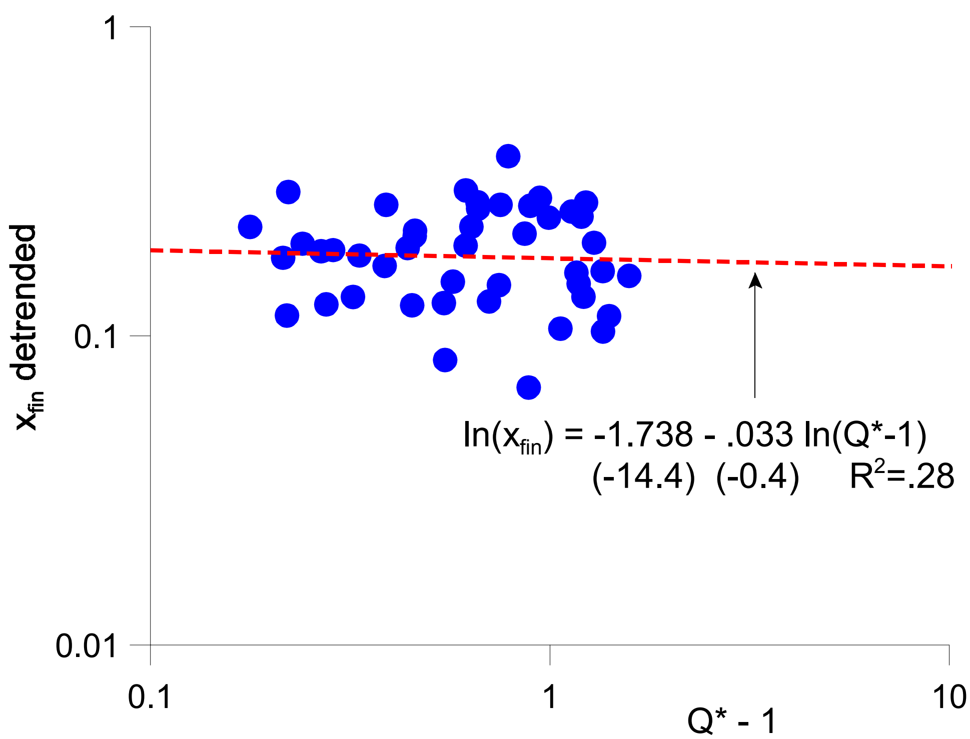


Figure 7. Scatterplots of regressions of the IPO value (y_{fin}) and SEO value (x_{fin}) as percentages of the U.S. capital stock on Tobin's Q, 1955-2001.

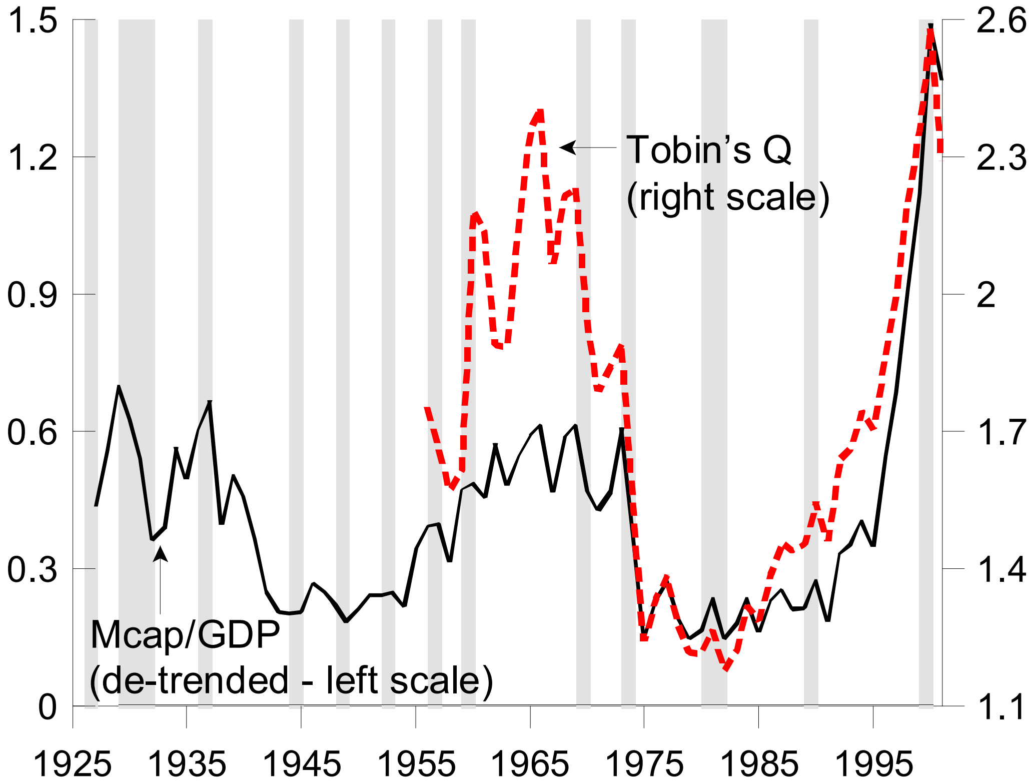


Figure 8: $MCAP/GDP$, 1927-2001, and Tobin's Q, 1955-2001.

6.2.2 Using the ratio of stock market value to GDP as a proxy for Q

Given that the series for the value of seasoned offerings is available from 1927, it would be useful to have a continuous measure of Q that also goes back that far. But using Compustat limits the coverage to 1955-2001. Because of this, we next work with the de-trended ratio of stock market capitalization to output, which is available continuously from before 1927, as a proxy for Q. This measure will be a noisier measure of Q^* than Q itself, and the estimate of β in Eqs. (12) and (13) will be biased towards zero. We start by getting residual u_t from the regression

$$\frac{MCap_t}{GDP_t} = a + bt + u_t.$$

Defining the simple mean of $\frac{MCap_t}{GDP_t}$ as μ, we then set

$$Q_t^* = \mu + u_{t-1}.$$

Figure 8 includes the series, along with our Q's as measured with the available Compustat data. Since the former does not always exceed unity, we run regressions without subtracting one from Q^* before taking logs.

Table 3. Regressions of IPOs (y_{fin}) and SEOs (x_{fin}) as percent of K with $Mcap/GDP$ as a proxy for Q^*, 1955-2001.

	Dependent variable			
	$\ln(y_{fin})$	$\ln(y_{fin})$	$\ln(x_{fin})$	$\ln(x_{fin})$
$\ln(Q^*)$	0.710	0.845	-0.061	-0.080
	(2.64)	(3.23)	(-0.60)	(-0.76)
r_t		0.195		-0.027
		(2.38)		(-0.84)
trend	0.054	0.041	0.017	0.018
	(4.92)	(3.46)	(4.02)	(3.93)
constant	-3.791	-3.823	-1.789	-1.784
	(-9.14)	(-9.71)	(-11.45)	(-11.37)
R^2	.426	.495	.282	.295
N	45	45	45	45

Note: t-statistics are in parentheses.

Table 3 presents the findings using data from 1955-2001 only. We do this to compare the results with our new measure of Q^* based on stock market capitalization to those obtained in Table 2 using estimates of Q^* based on firm-level data. Figure 9 includes scatterplots of the regressions that exclude the commercial paper rate. The results in the y_{fin} regressions are weaker with the new proxy for Q, but the coefficients on Q^* remain statistically significant at the five percent level. The x_{fin} regressions continue to show negative but not statistically significant coefficients on Q^*. The commercial paper rate (r_t) remains marginally significant in the y_{fin} equation and not significant in the y_{fin} equation.

We now proceed to estimate our investment equations with the new proxy for Q over the full 1927-2001 period. The results, shown in Table 4, are qualitatively the same as for the 1955-2001 period, though the coefficients on the log of Q^* are a bit smaller in the y_{fin} equations. They remain statistically significant, however, at the five percent level. The commercial paper rate is no longer statistically significant, though it remains positive. Once again, Q^* is not significant in the x_{fin} equations. Figure 10 presents the scatterplots.

In terms of the parameters in Eqs. 12 and 13 in the model, our regression results imply that γ is indeed much larger than μ. If we use our estimate of 1.2 for the coefficient on the log of $Q^* - 1$ from Table 2 as the elasticity of IPO value, this implies a value of 1.833 for μ. If we use the estimate of 0.637 from Table 1, this implies that μ is about 2.6. On the other hand, the largest coefficient estimate that

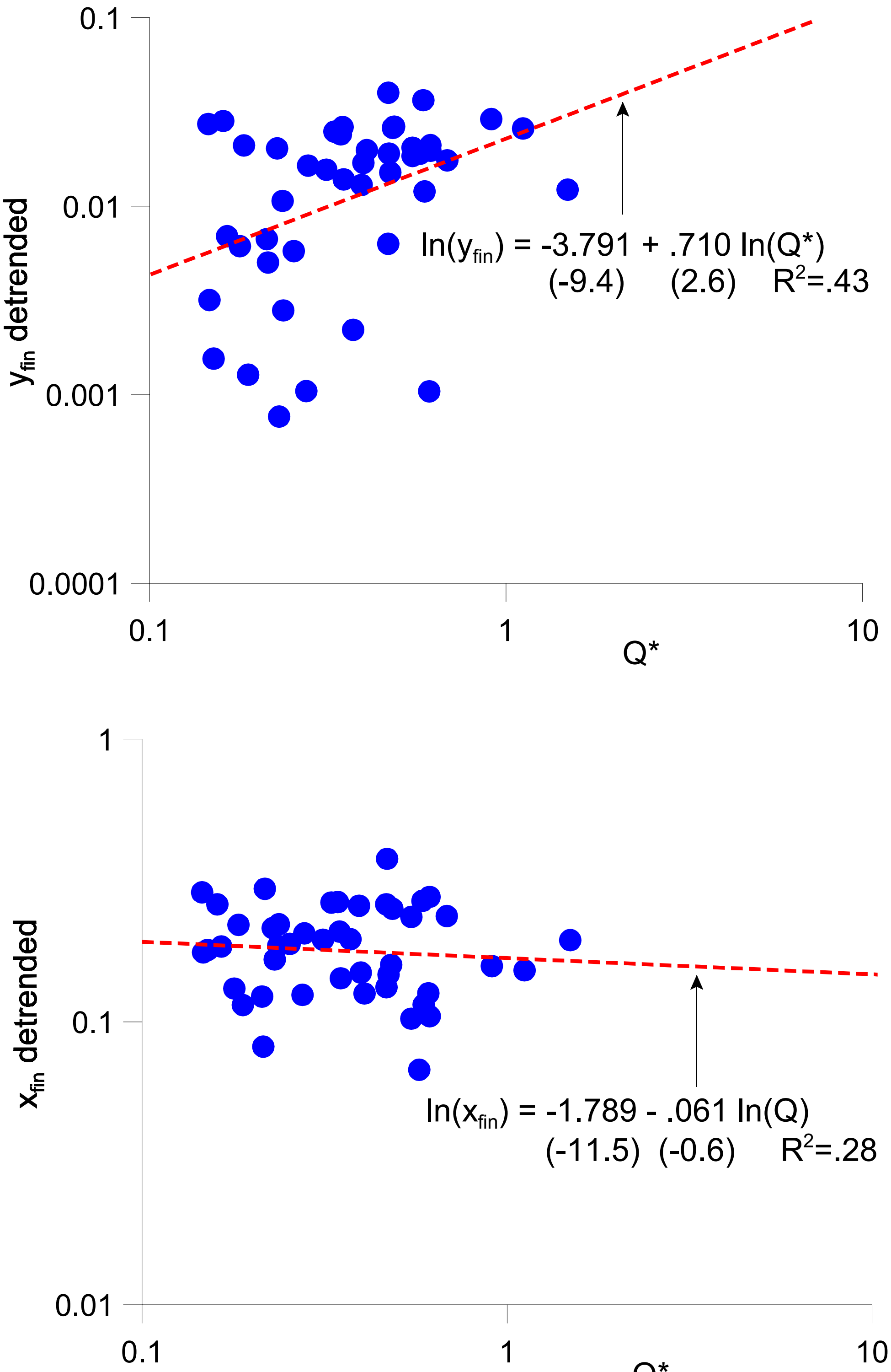


Figure 9. Scatterplots of regressions of the IPO value (y_{fin}) and SEO value (x_{fin}) as percentages of the U.S. capital stock on MCAP/GDP, 1955-2001.

Table 4. Regressions of IPOs (y_{fin}) and SEOs (x_{fin}) as percent of K with $Mcap/GDP$ as a proxy for Q^*, 1927-2001.

	Dependent variable			
	$\ln(y_{fin})$	$\ln(y_{fin})$	$\ln(x_{fin})$	$\ln(x_{fin})$
$\ln(Q^*)$	0.688	0.622	-0.063	-0.106
	(2.67)	(2.35)	(-0.34)	(-0.56)
r_t		0.039		0.026
		(1.12)		(1.03)
trend	0.035	0.033	0.012	0.011
	(5.71)	(5.28)	(2.73)	(2.40)
constant	-4.260	-4.328	-2.009	-2.054
	(-11.75)	(-11.79)	(-7.80)	(-7.87)
R^2	.351	.362	.102	.116
N	72	72	72	72

Note: t-statistics are in parentheses.

we obtain on the log of $Q^* - 1$ is only 0.042 (from Table 1), and this implies a value of nearly 25 for γ.

We can also compare the actual coefficients that we obtain on $Q^* - 1$ with those reported by Hayashi (1982) for regressions of firm-level investment on Q. His coefficient of 0.045 is only slightly larger than the largest coefficient of 0.042 obtained in our x regressions. In our y regressions, however, the coefficients of 1.211 and 0.637 on $Q^* - 1$ are 27 and 14 times larger, respectively, than those obtained by Hayashi. Although he used firm level data and we use aggregate time series here, it is striking how close our coefficients for incumbent investment match Hayashi's findings for firms generally, and how much more responsive new investment is to fluctuations in Q.

6.3 Regressions with the number of IPOs

At the end of Section 5, we mentioned that the structural equation (11) implies a zero relation between Q and n. On the other hand, n raises the marginal product of capital and, if this raises the interest rate, will lower Q^*. The deterministic case, at least, and equations (14), and (19), predict a negative relation as a comparative steady-state outcome. To check this, we build a series for the number of IPOs from 1927-2001 using Ritter (2003, Table 5, p. 6) for 1975-2001, and ratio-splicing the

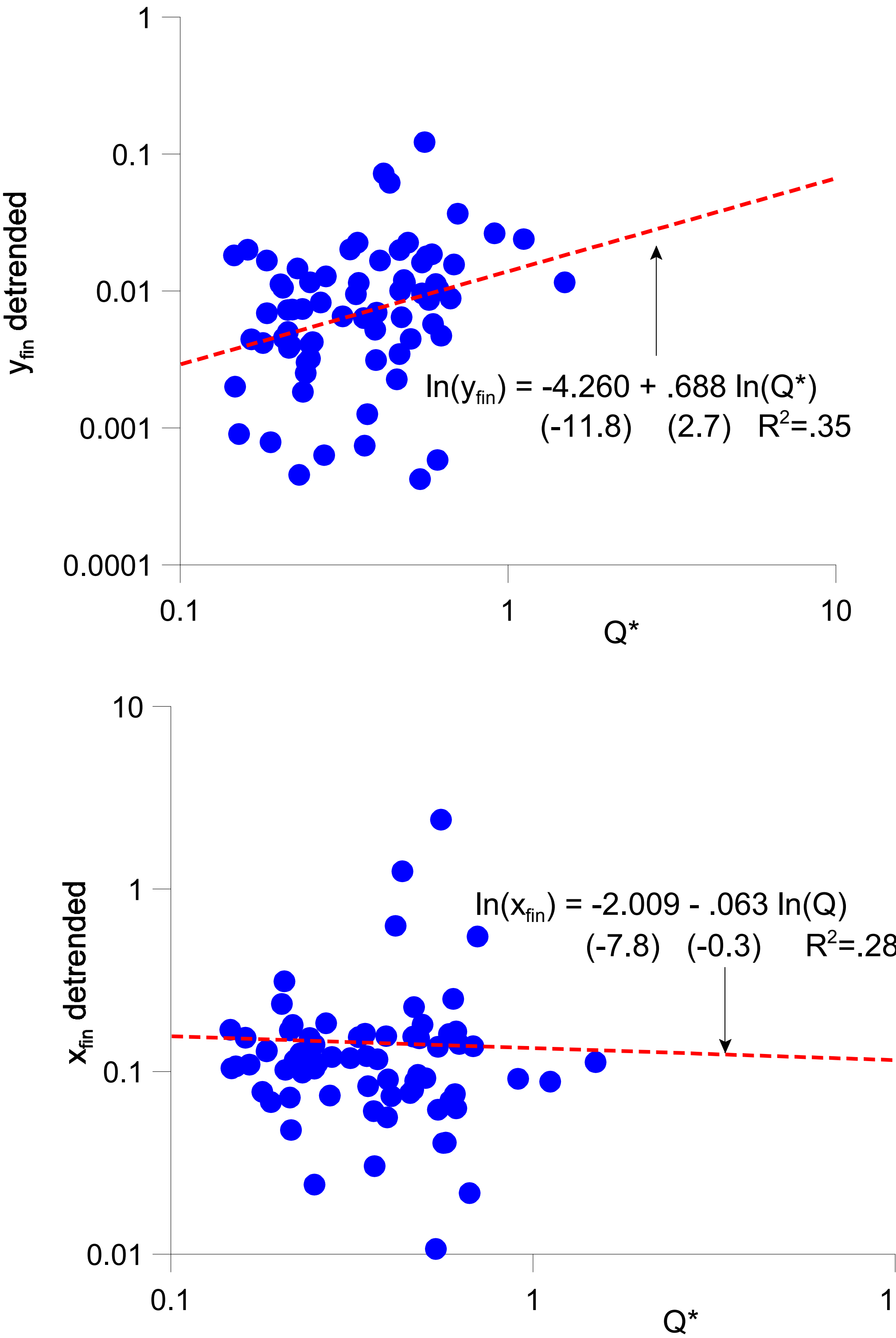


Figure 9. Scatterplots of regressions of the IPO value (y_{fin}) and SEO value (x_{fin}) as percentages of the U.S. capital stock on MCAP/GDP, 1927-2001.

number of new listings on the CRSP database from 1927-74.[15]

Table 5 presents the regressions. The coefficient on $Q^* - 1$ is not statistically significant for 1955-2001 in the first column, and the coefficient on Q as measured by $Mcap/GDP$ is not significant for the 1927-2001 period either. In all cases, however, the sign is negative, and is even statistically significant in the second column for 1955-2001. This confirms the prediction of the model.

Table 5. Regressions of the number of IPOs (n) on $Q^* - 1$ and with $Mcap/GDP$ as a proxy for Q^*.

	Dependent variable: n		
	1955-2001	1955-2001	1927-2001
$\ln(Q^* - 1)$	-0.164		
	(-1.09)		
$\ln(MCAP/GDP)$		-0.519	-0.314
		(-3.53)	(-1.48)
r_t	0.211	0.185	0.103
	(4.12)	(4.03)	(3.67)
trend	0.111	0.114	0.083
	(15.02)	(17.20)	(16.58)
constant	0.507	0.053	-0.990
	(2.59)	(0.24)	(-3.35)
R^2	.905	.925	.835
N	45	45	72

Note: t-statistics are in parentheses.

7 Long-run growth when z is constant

This is an endogenous growth model. The growth rate is random and depends on z. But we can solve for it when z is constant. We are interested in how the growth rate depends on the adjustment cost parameters, especially the parameters of C^*. Let

$$U(c) = \frac{1}{1-\sigma} c^{1-\sigma}.$$

[15] We obtain similar results using the number of new listings on CRSP for the entire 1927-2001 period instead of the Ritter-CRSP figures. The two series have a correlation coefficient of 0.96.

Let g be the long-run growth rate of consumption. If g is constant, it must equal the rate of growth of capital $x + \kappa y - \delta$, i.e.,

$$g = x + z_2 y - \delta. \tag{14}$$

Then (6) gives us

$$Q^* = \beta (1+g)^{-\sigma} Q, \tag{15}$$

The FOCs (7) and (9) read

$$C'(x) = Q^* - 1, \tag{16}$$

and

$$C^{*\prime}(y) = Q^* - 1. \tag{17}$$

With (5), we have 5 equations in the 5 unknowns (g, x, y, Q, Q^*).

We first use (5) and (15) to eliminate Q and solve for Q^*:

$$\begin{aligned} Q &= z_1 - C(x) - x + (1 - \delta + x) \beta (1+g)^{-\sigma} Q \quad \Longrightarrow & (18) \\ Q^* &= \frac{\beta (1+g)^{-\sigma} (z_1 - C(x) - x)}{1 - (1 - \delta + x) \beta (1+g)^{-\sigma}}, & (19) \end{aligned}$$

which reduces the system to 4 equations (14), (16), (17), and (19) in the 4 unknowns (g, x, y, Q^*).

7.0.1 Special case when $\sigma = 0$

Let $U(c) = c$. Then $(1+g)^{-\sigma} = 1$ and the system becomes recursive so that (x, Q^*) do not depend on the form of $C^*(y)$. We can first solve for x and Q^*, and then we can get y. Noting that now and $Q^* = \beta Q$, the 2 equations are (16) and

$$Q^* = \frac{z - C(x) - x}{\beta^{-1} - (1 - \delta + x)},$$

They reduce to a single equation in x:

$$1 + C'(x) = \frac{z - C(x) - x}{\beta^{-1} - (1 - \delta + x)}.$$

Neither x nor Q^* depends on the parameters of C^*. Let us assume $K_0 = 1$, a harmless normalization. The growth rate is

$$g = x - \delta + z_2 y.$$

Therefore we simply need to solve for y as a function of μ which only y depends on. Solve (17)

$$y = (C^{*\prime})^{-1} (Q^* - 1).$$

So, if we change the parameters of C^* without changing anything else, we affect the growth rate solely through the entry of new capital at a faster rate. Suppose

$$C^*(y) = \frac{1}{\theta} y^\lambda \quad \Longrightarrow y = \frac{\theta}{\lambda} (Q^* - 1)^{1/(\lambda-1)}.$$

Here θ can be thought of as the financial development parameter. We can choose z so that Q^* is about 1.3 and set $\lambda = 2$. Then

$$y = (0.15)\,\theta$$

Therefore the growth rate would be

$$g = x - \delta + (0.15)\, z_2 \theta$$

Since x does not depend on θ,

$$\frac{dg}{d\theta} = (0.15)\, z_2.$$

Financial development and growth.—A lower C^* may reflect the presence of analysts, investment bankers, venture capitalists and stock-market traders – people that predominate in financially developed countries. Because of the relative novelty of the ideas and technologies of new firms and the human-capital intensity of evaluating their prospects, it is probable that countries differ more in their C^*'s than they do in their C's. At a stretch one could link this model to the data on financial development and growth.

8 Other issues

Other evidence on entrants vs. incumbents.—The question of when we may expect to see more IPOs is a part of the more general question of when we should expect entrants to outperform incumbents or to gain market share. Chirinko and Schaller (1995) find investment of mature firms responds more to Q than investment of young firms. Since IPO-ing firms are young, this evidence runs counter to ours. On the other hand, business cycle research reveals an elastic movement of labor at the extensive margin (i.e., employment) compared to the intensive margin (i.e., hours per worker). This agrees with our findings that entrants respond more to Q than do incumbents. But then again, Boeri and Cramer (1992) find that incumbent firms accommodate the bulk of cyclical fluctuations whereas entrants account more for the low-frequency movements in employment. On the whole, the evidence is mixed.

Thick-market externalities and IPO waves.—A mechanism that would amplify the effects of shocks on investment is the presence of thick-market externalities: Pecuniary (Shleifer 1986) and non-pecuniary (Diamond 1982, Pagano 1989 and Veldcamp

2003). They may explain why C^* is less convex than C when considered a function of aggregate y.[16] They would bring a second external effect into the model.

9 Conclusion

We found that the Q-theory of investment explains IPOs rather well. It does a better job with the investment of entering firms than it does with the investment of incumbents, in the sense that entering firms responds much more elastically to Q than do incumbents. The response is real, not merely financial.

References

[1] Baker, Malcolm, and Jeffrey Wurgler. "The Equity Share in New Issues and Aggregate Stock Returns." *Journal of Finance* 55, no. 5 (October 2000): 2219-2257.

[2] Berry, Thomas S. "Production and population since 1789: revised GNP series in constant dollars", Bostwick Paper No. 6 (The Bostwick Press, Richmond, VA), 1988.

[3] Boddy, Raford, and Michael Gort. "The Substitution of Capital for Capital." *Review of Economics and Statistics*, Vol. 53, No. 2. (May, 1971): 179-188.

[4] Boeri, Tito, and Ulrich Cramer. "Employment Growth, Incumbents and Entrants: Evidence from Germany." *International Journal of Industrial Organization* 10, no. 4 (December 1992): 545-565.

[5] Campbell, Jeffrey. "Entry, Exit, Embodied Technology, and Business Cycles." *Review of Economic Dynamics* 1, no. 2, (April 1998): 371-408.

[6] Chirinko, Robert and Huntley Schaller. "Why Does Liquidity Matter in Investment Equations?" *Journal of Money, Credit and Banking* 27 (May 1995): 527-548.

[7] Choe, Hyuk, Ronald Masulis and Vikram Nanda. "Common Stock Offerings Across the Business Cycle." *Journal of Empirical Finance* 1 (1993): 3-31.

[8] *Compustat database.* (2001). New York: Standard and Poor's Corporation.

[9] Cummins, Jason and Matthew Dey. "Taxation, Investment, and Firm Growth with Heterogeneous Capital." NYU, May 1998.

[16] For instance, the adjustment cost could also depend negatively on the aggregate investment of all new firms, $\mathbf{y}$, as in $C^*\left(\overset{+}{y}, \overset{-}{\mathbf{y}}\right)$, a non-pecuniary external effect à la Diamond (1982).

[10] DeJong, David N., and Beth F. Ingram. "The Cyclical Behavior of Skill Acquisition." *Review of Economic Dynamics* 4, no. 3 (July 2001): 536 - 561.

[11] Diamond, Peter. "Aggregate Demand Management in Search Equilibrium." *Journal of Political Economy* 90, no. 5, (October 1982): 881-94."

[12] Gort, Michael, and Raford Boddy, "Vintage Effects and the Time Path of Investment in Production Relations," *Studies in Income and Wealth* 31, Columbia University Press (for NBER) (1967): 395 - 422.

[13] Gort, Michael and Seong-Hoon Lee. "The Life Cycles of Industrial Plants.;" RAND Journal, forthcoming.

[14] Hayashi, Fumio. "Tobin's Marginal q and Average q: A Neoclassical Interpretation." *Econometrica* 50, No. 1. (Jan., 1982), pp. 213-224.

[15] Jovanovic, Boyan, and Peter L. Rousseau. "Vintage organization capital." Working Paper No. 8166, National Bureau of Economic Research, Cambridge MA, March 2001.

[16] Jovanovic, Boyan, and Peter L. Rousseau. "Why Wait? A Century of Life Before IPO." *American Economic Review* (Papers and Proceedings) 91, no. 2 (May 2001): 336-341.

[17] Jovanovic, Boyan, and Peter L. Rousseau. "The Q-Theory of Mergers." *American Economic Review* (Papers and Proceedings) 92, no. 2 (May 2002): 198 - 204.

[18] Kendrick, John. *Productivity Trends in the United States.* Princeton University Press, Princeton, NJ, 1961.

[19] Kuznets, Simon S. *Capital in the American Economy: Its Formation and Financing.* Princeton University Press, Princeton, NJ, 1961a.

[20] Kuznets, Simon S. "Annual estimates, 1869-1955." Manuscript, Johns Hopkins University, Baltimore, MD, 1961b.

[21] Lee, Inmoo, Scott Lockhead, Jay Ritter, and Quanshui Zhao. "The Costs of Raising Capital." *Journal of Financial Research* 19, no.1 (Spring 1996): 59-74.

[22] Lowry, Michelle. "Why Does IPO Volume Fluctuate So Much?" *Journal of Financial Economics* (2002):

[23] Moskowitz, Tobias J., and Annette Vissing-Jorgensen. "The Returns to Entrepreneurial Investment: A Private Equity Premium Puzzle?" *American Economic Review* 92, no. 4 (September 2002): 745 - 778.

[24] Pagano, Marco. "Endogenous Market Thinness and Stock Price Volatility." *Review of Economic Studies* 56, no. 2 (April 1989): 269-87.

[25] Pastor, Lubos, and Pietro Veronesi. "IPO Waves and Market Valuation." Manuscript, University of Chicago Graduate School of Business, June 2003.

[26] Ritter, Jay R. "The Hot Issue Market of 1980." Journal of Business 57 (1984): 215-240.

[27] Ritter, Jay R. "Some Factoids About the 2002 IPO Market." Manuscript, University of Florida, January 2003.

[28] Romer, Paul. "Endogenous Technological Change." *Journal of Political Economy* 98, no. 5, Part 2 (October 1990): S71 - 102.

[29] Shleifer, Andrei. "Implementation Cycles." *Journal of Political Economy* 94, no. 6 (December 1986): 1163-90.

[30] United States Bureau of Economic Analysis, *Survey of Current Business*. Government Printing Office, Washington, DC, 2002.

[31] University of Chicago Center for Research on Securities Prices. *CRSP Database*. University of Chicago Center for Research on Securities Prices, Chicago, IL, 2002.

[32] Veldcamp, Laura. "Media Frenzies in Markets for Financial Innovation." Manuscript, INSEAD, June 2003.

10 Appendix

10.1 The equilibrium saving decision

Asset markets.—We assume only a stock market. A household owns shares of firms, and dividends are its only income. The number of households is normalized to unity. Because K grows over time, let us define shares in terms of pieces of capital rather than firms. That is, let N be the number of units of incumbent capital that the household owns. The ex-dividend price of a share of incumbent capital is Q^*. The price of an IPO-ing firm is also Q^*. Right after the incumbents have paid their dividends, their shares become perfect substitutes with the shares of the entrants. Since Q^* depends only on z we can write the budget constraint as follows:

$$\begin{aligned} c + Q^*(z)(N' - N) &= (z_1 - x[z] - C[x(z)])N \\ &\equiv \phi(z) N. \end{aligned} \tag{20}$$

In this budget constraint we have inserted the incumbent firms' equilibrium investment decisions $x[z]$.

The savings problem.—The consumer's state is (z, N), and his Bellman equation is

$$w(z, N) = \max_{N'} \left\{ U[\phi(z) N - Q^*(z)(N' - N)] + \beta \int w(z', N') \, dF(z', z) \right\}. \tag{21}$$

The FOC is

$$-U'(c) Q^*(z) + \beta \int w_2(z', N') \, dF(z', z). \tag{22}$$

Now the envelope theorem gives us

$$w_2(z, N) = U'(c)[\phi(z) + Q^*(z)] \tag{23}$$

which, with (22) implies

$$Q^*(z) = \beta \int \frac{U'(c')}{U'(c)} [\phi(z') + Q^*(z')] \, dF(z', z).$$

which along with (5) and (6) implies (10).

Savings = Investment.—Define the optimal consumption and savings policies by

$$c = \psi_c(z, N) \quad \text{and} \quad N' = \psi_N(z, N).$$

Equilibrium requires that $N = K$, and we ask that equilibrium actions respect this identity. This will occur if

$$\psi_N(z, K) = (1 - \delta + x[z] + z_2 y[z] K_0) K. \tag{24}$$

10.2 The planner's problem

The planner's problem is described by the following Bellman equation

$$v(z,K)=\max_{x,y,K'}\left\{U\left(\left[z_1-x-z_2yK_0-C(x)-z_2C^*(y)K_0\right]K\right)+\beta\int v(z',K')\,dF(z',z)\right\}$$

s.t.

$$[1-\delta+x+z_2yK_0]\,K=K' \tag{25}$$

This constraint can be solved for x:

$$x=\frac{K'}{K}-z_2yK_0-1+\delta.$$

Eliminating x, the Bellman equation now reads

$$v(z,K)=\max_{y,K'}\left\{\begin{array}{c}U\left(\left[z_1+1-\delta-C\left(\frac{K'}{K}-z_2yK_0-1+\delta\right)-z_2C^*(y)K_0\right]K-K'\right)\\+\beta\int v(z',K')\,dF(z',z)\,.\end{array}\right\} \tag{26}$$

The planner's FOC's.—Differentiating in (26) with respect to y, we obtain the first necessary condition for the planner's optimum:

$$C'(x)-C^{*\prime}(y)=0. \tag{27}$$

Comparing this with (7) and (9) we see that the planner also equates the marginal costs of the two kinds of investment. This is because the external effects of x and y are the same.

Differentiating in (26) with respect to K',

$$U'(c)\left[1+C'(x)\right]=\beta\int v_2(z',K')\,dF(z',z)$$

which is to be compared to (22) which, when combined with (7), reads

$$-U'(c)\left[1+C'(x)\right]=\beta\int w_2(z',N')\,dF(z',z)\,.$$

The external effect creates a divergence between $w_2(z,K)$, the equilibrium incentive to save and $v_2(z,K)$, the planner's incentive to save. According to [23], the equilibrium incentive at $N=K$ is

$$w_2(z,K)=U'(c)\left[\phi(z)+Q^*(z)\right],$$

where

$$\phi(z)=(z_1-x[z]-C[x(z)])\quad\text{and}\quad Q^*(z)=1+C'(x),$$

i.e.,

$$w_2(z,K)=U'(c)\left[z_1-x-C(x)+1+C'(x)\right].$$

To calculate the planner's incentive, we use the envelope condition in (26) to conclude that

$$v_2(z,K) = U'(c)\left[z_1 + 1 - \delta - C(x) - z_2 C^*(y) K_0 + C'(x)\frac{K'}{K}\right]. \tag{28}$$

Proposition 1 *For all z for which $x(z) > \delta$, then*

$$v_2(z,K) > w_2(z,K).$$

Proof. From (25) and (28),

$$\begin{aligned}
v_2(z,K) &= U'(c)\left[z_1 + 1 - \delta - C(x) - z_2 C^*(y) + C'(x)(1 - \delta + x + z_2 y K_0)\right] \\
&= U'(c)\left[z_1 - C(x) + 1 + C'(x) - x + x - \delta - z_2 C^*(y) K_0 + C'(x)(-\delta + x + z_2 y K_0)\right] \\
&= w_2(z,K) + U'(c)\left[x - \delta - z_2 C^*(y) K_0 + C'(x)(-\delta + x + z_2 y K_0)\right] \\
&= w_2(z,K) + U'(c)\left((x-\delta) C'(x) - z_2\left[C^*(y) - yC'(x)\right]\right) K_0 \\
&= w_2(z,K) + U'(c)\left[z_2\left[yC^{*\prime}(y) - C^*(y)\right] K_0 + (x-\delta) C'(x)\right]
\end{aligned}$$

using (27). By the convexity of C^*, $yC^{*\prime}(y) - C^*(y) > 0$, and the claim follows. ■

The condition $x(z) > \delta$ is sufficient but not necessary, and so the converse is not necessarily true. If $\delta = 0$, however, the inequality holds in all states and then the Proposition implies that the planner would prefer a higher growth rate in all states.

Finally, this welfare result concerns capital creation in general, and not new-firm capital in particular.

10.3 Descriptive statistics for the data

In this appendix we present descriptive statistics for the data used in our analysis over the period from 1955 to 2001. Table 6 presents the time series means, standard deviations, and annual trend growth rates. Table 7 presents the correlations of the data after de-trending each series.

Table 6. Descriptive Statistics, 1955-2001

	mean	std. deviation	trend growth (%)
y_{real}	73.6	65.2	4.10
y_{fin}	.091	.096	6.36
x_{real}	.135	.031	-0.63
x_{fin}	.286	.121	0.81
Q^*	1.73	.396	0.81
M/GDP	.412	.266	4.58
r_{real}	2.57	2.03	
n	165	198	8.53

Table 7. Correlations for the De-trended Series, 1955-2001

	y_{real}	y_{fin}	x_{real}	x_{fin}	Q^*	M/GDP	r_{real}	n
y_{real}	1							
y_{fin}	.332	1						
x_{real}	.240	-.045	1					
x_{fin}	-.066	-.019	-.179	1				
Q^*	.609	.528	.222	-.047	1			
M/GDP	.847	.352	.290	.056	.794	1		
r_{real}	-.238	-.127	-.020	-.082	-.101	-.218	1	
n	-.252	.414	-.264	.318	.031	-.278	.171	1

In the tables y_{real} is the average investment of new stock market listings, x_{real} is the average investment of incumbents, y_{fin} is the value of IPOs as a percentage of the U.S. capital stock, $x_{fin}$is the value of seasoned offerings as a percentage of the U.S. capital stock, and r_{real} is the real commercial paper rate.