Firm Size, Equity Financing and Innovation Activity*

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Job Market Paper

Abstract

I document a stark reallocation of innovation activity, measured by both R&D expenditures and patenting, from large to small public manufacturing firms in the U.S. over the period 1976 to 2005. Whereas in the past, different sized firms seemed to appropriate close to a constant proportion of their revenues to R&D, nowadays, small firms contribute orders of magnitude more to these efforts as compared to their larger counterparts. In this paper, I relate the rise in innovation intensity of small firms to their increased use of external equity financing. Next, I establish that two financial changes, decreased costs of issuing equity and tax rates on corporate distributions, are quantitatively important drivers of the innovation and equity trends. To do so, I build a theoretical model with firm dynamics, in which heterogeneous firms choose innovation efforts and finance their R&D via internal and costly external funds. In the absence of taxes and external financing costs, the model generates a negative relationship between innovation incentives and firm size, inducing a disproportionate investment in R&D by small firms. Introducing these frictions into the model disrupts the monotonic relationship between R&D intensity and firm size. The model, estimated using U.S. public firm-level data, is able generate a sizable rise in innovation intensity and equity financing use among small firms as a result of changes in dividend tax rates and equity issuance costs.

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1 Introduction

Technological progress, stemming from innovation activity, is widely acknowledged as the primary engine of long-run economic growth. In the United States, the business sector is the dominant contributor to innovation efforts, accounting for approximately 70 percent of total research and development (R&D) expenditures and 85 percent of patents granted by the United States Patent and Trademark Office (USPTO) to domestic entities. Within the business sector, however, there is vast heterogeneity in innovation performance. Thus, a literature has developed to understand what factors drive firm innovation. Seminal empirical studies[1] showed that, in samples from the late 1970s, manufacturing firms consistently allocated a constant proportion of their revenue to R&D activities. Recent empirical evidence[2], however, exhibits a negative relationship between firm size and innovation intensity[3] on average, suggesting that smaller firms tend to invest a greater proportion of sales in innovation activities relative to their larger counterparts.

In this paper, I reconcile the discrepancy between these studies by documenting that small firms have accounted for a disproportionate share of the boost in manufacturing innovation activity over the past forty years. I link the rise in small firms' innovation intensity to their increased use of external equity financing. I then establish that two financial changes, decreased costs of issuing equity and decreased tax rates on corporate distributions, are quantitatively important drivers of the innovation and equity trends.

The first part of this paper establishes a new empirical fact regarding the changing relationship between firms size and innovation activity. I find that while public manufacturing firms, both large and small, seemed to allocate close to a constant proportion of their revenues to R&D in the mid-1970s, the *conditional* correlation between firm size and R&D expenditures has been gradually decreasing over the period 1976 to 2005. Although the relationship between firm size and R&D intensity has been negative on average, I find that this average is characterized by a stark change from a constant to negative relationship beginning in the late 1970s. In other words, smaller firms have become more R&D intensive relative to large firms over the last forty years. This trend is also prevalent in alternative measures of innovation, such as the number of patent grants and their respective citations[4]. In addition, these findings are robust to various measures of firm size, such as sales, assets, and employment.

The second part of this paper is dedicated to understanding which factors explain this apparent change in the relationship between firm size and innovation activity. Interestingly, I observe that smaller firms have not only become more R&D intensive, but also simultaneously increased their use of external funds. More specifically, I observe that: 1) small firms have begun to acquire more

[1] See Bound et al. (1984) and Cohen et al. (1987).

[2] See Akcigit (2010) and Akcigit and Kerr (2010).

[3] Innovation intensity is defined as R&D expenditures or patenting activity scaled by a measure of firm size.

[4] The number of citations received by a patent has been validated as a good proxy for patent value in the work of Hall et al. (2005).

public equity financing and 2) the relationship between public equity financing intensity[5] and firm size has also become increasingly negative. The joint observation of these changes prompts the following question: Are the trends in small firms' innovation behavior and equity financing related?

Since innovation investments demand a significant financial resource commitment, are difficult to collateralize, highly uncertain, and are often profitable only at some point in the future, innovation decisions are expected to be sensitive to financial frictions that firms face. In fact, previous empirical studies (Brown et al. (2009), Carpenter and Petersen (2002), Hall and Lerner (2009)) have found that while larger firms seem to rely on internal funds (cash-flows) to finance their R&D activity, small firms' R&D is highly dependent on the ability to access external financing. Costs associated with acquiring external funds thus introduce a wedge in the required returns to innovation among different sized firms. Literature on the financing of innovation has also established that equity, as opposed to debt, is a more appropriate source of external financing for R&D intensive firms. This claim is supported by considerable cross-sectional evidence of a negative correlation between firm-level R&D intensity and leverage in the U.S.[6] Empirically, I document that over the period 1976 to 2005, firms in my sample increase their R&D expenditures following public equity issues through either Initial Public Offerings (IPOs) or Seasoned Equity Offerings (SEOs), but not following issuance of debt. In addition, I find an absence of an increasing trend in debt financing and decreasing trends in per-period cash-flows generated by small firms. This evidence strongly suggests that that these trends are in fact related: as small firms increased their R&D intensity over the period, lack of sufficient internal funds has required them to issue increasing amounts of public equity.

Given this association between innovation and equity finance, I propose financial changes as important drivers of these trends. During this period, the U.S. underwent two important developments: 1) an evident decrease in the underwriting spreads associated with equity issues[7] and 2) a decrease in effective marginal tax on dividend distributions as a result of increased institutional holdings of equity securities. In my sample, the average gross spread paid on equity issues declined by 14 percent (from 7.2 to 6.3 percent of proceeds), 13 percent for IPOs and 16 percent for SEOs, over the period 1976 to 2005. McGrattan and Prescott (2005) estimate that the effective tax rate on corporate distributions fell from an average of 41 to 17 percent from the 1970s to the 1990s. I hypothesize that both changes reduced the wedge in the costs of innovation between financially constrained and unconstrained firms.

In order to quantitatively assess the contribution of financial changes to the aforementioned trends, I build a general equilibrium model of firm dynamics. In the model, monopolistically competitive firms are heterogeneous in firm-specific labor productivity. Small firms are those with low

[5]Equity financing intensity is defined as the net proceeds from the sale of stock scaled by a measure of firm size.

[6]See Friend and Lang (1988), Hall (1992), Bhagat and Welch (1995) and Itenberg and Stangebye (2013).

[7]An underwriting spread, also referred to as the gross spread, is defined as the difference between the share price offered to the public and the per-share proceeds received by the issuing company. The interpretation is that this fee is the compensation to the underwriters of the issue for legal expenses, management fees, commission and risk. Underwriting spreads are direct costs associated with the issue, but the are also indirect costs in the form of initial returns earned by investors as a result of underpricing on the first day of issue. I abstract from these types of costs in this paper.

sales due to low productivity. Individual firm productivity evolves with successful innovations, the likelihood of which varies with the resources allocated to R&D activity. Increase in firm productivity leads to a rise in profits through the reduction of marginal costs of production relative to competitors. R&D investment is costly and firms that do not generate sufficient per-period cash flows must finance these expenditures externally. Low profits in combination with fixed cost of production limit the amount of R&D that small firms can finance with internal funds, causing them to issue equity. Firms face costs of raising external funds and are subject to taxes if the dividend payout is positive. In addition, endogenously determined markups respond to entry and exit of firms, introducing a novel channel through which financial conditions can affect the profitability of incumbent firms. In the absence of dividend taxation and equity issuance cost, large and small, cash constrained firms face the same costs of innovating. In this frictionless case, the model generates a negative relationship between innovation incentives and firm size, inducing a disproportionate investment in R&D by small firms. Introducing these frictions into the model disrupts the monotonically decreasing relationship between R&D intensity and firm size.

To complete the analysis, I perform a counterfactual experiment to assess the relative quantitative importance of the changes in taxes and equity issuance costs. I estimate the main structural parameters of the model using data from the period 1996-2005. In the estimation, I require the model to replicate the observed differences between large and small firms along several static (R&D intensity, labor productivity) and dynamic (growth and transition rates) dimensions. I then increase the dividend tax and equity issuance costs to their respective past levels and show how different firm policies would look today had these frictions remained constant. This experiment allows me to isolate the effects of dividend taxation and issuance costs from other financial and policy changes that occurred during the same period. Comparing model output to observed firm innovation and equity financing in the past, I show that, as a result of these two changes, the model generates: 1) one third of the observed increase in innovation intensity among small firms; 2) a 50 percent decrease in the correlation between firm size and innovation intensity; and 3) a 30 percent increase in external equity use among small firms. In addition, growth in the economy rises by 39 basis points and welfare increases by 13 percent in consumption-equivalent terms. Although most of the increase in welfare comes as a result of increased innovation on the part of financially constrained firms, a nontrivial, one-tenth share of the change comes through the effect of increased competition driving down the markups in the economy.

This paper is related to several strands in the literature. One contribution of this paper is the synthesis of two previously disjoint areas of study: one strand of literature which focuses on understanding the effects of firm-level innovation on firm dynamics, featuring Klette and Kortum (2004), Lentz and Mortensen (2008), Acemoglu et al. (2013), Akcigit (2010), Akcigit and Kerr (2010), and a second which explores the role of financial frictions in canonical industry dynamics models of Hopenhayn (1992) and Jovanovic (1982), such as Cooley and Quadrini (2001), Gomes (2001), Clementi and Hopenhayn (2006). Also, since the broad goal of this paper is to study the effect of financial changes on firms' propensity to innovate and hence improve productivity, my paper falls within the literature which explores the impact of financial deregulation and financial development on economic development[8]. The contribution of the proposed study is the structural analysis of the novel channel through which financial changes cause a reallocation of innovation activity among different sized firms. There have been several studies which tie changes in access to external financing to firm innovation activity. Amore et al. (2013) find that staggered deregulation of banking across U.S. states led to the rise in the quantity and quality of patents while Chava et al. (2013) find differential impacts of the same deregulation on private and public firms. Kortum and Lerner (2000) consider the effect of the spur in venture capital financing and find that this development may have contributed as much as 10 percent of industrial innovation between 1983 to 1992. Although I recognize that venture capital could be an important source of external financing for start-ups, firms I am studying in this paper are quite different. Lastly, Brown et al. (2009) document the rise in equity issuance and R&D intensity for a subset of public firms in the high-technology sector during the 1990s and attribute these trends largely to supply shifts in both internal and external equity finance.

The rest of the paper is organized as follows. In section 2, I discuss the empirical trends in innovation intensity, equity financing, and firm size and briefly discuss changes in dividend taxes and equity issuance costs. In Section 3, I build a theoretical model and describe its features. I estimate the model and evaluate its fit in Section 4 and quantitatively assess the effect of financial changes on innovation and equity financing in section 5. Section 6 concludes.

2 Empirical Evidence

In this section, I present empirical support for the time trends over the past four decades in the relationships between:

- Firm size and R&D Intensity;
- Firm size and Equity Financing Intensity;
- Source of Financing and R&D Intensity.

I use a dataset consisting of an unbalanced panel of public manufacturing firms between the years 1976-2005, drawing information from three sources: S&P Compustat, NBER Patent Database, and SDC Global New Issues Database for the empirical analysis. Appendix A.1 describes the data sources in detail and Appendix A.2 describes the construction of the data items. What follows in this section is the empirical evidence for the stylized facts. Lastly, I briefly describe the changes in equity floatation costs and taxes on corporate distributions.

[8] Levine (2005) provides an excellent survey.

Table 2.1:
Innovation Share of Small Firms. Sample includes all domestic manufacturing firms with positive sales and coverage in Compustat. Patent counts and citations data is from NBER Patent Database. Small firms are those with less than $25 million in (real) annual sales. The table reports aggregate number of small firms in the same, small firm aggregate sales, R&D expenditures, patent and citation counts, as well as the shares of these totals as a fraction of all firm totals for the years 1980 and 2000.

	Totals			Share		
	1980	2000	% △	1980	2000	% △
Firm Counts	2,752	3,752	+ 36.34%	0.2424	0.2910	+ 20.08%
Sales ($ mil)	4,357,489	7,671,421	+ 76.05%	0.0016	0.0011	- 31.74%
R&D Expenditures ($ mil)	61,782	277,377	+ 348.96%	0.0033	0.0222	+ 578.19%
Patent Counts	11,730	31,672	+ 170.00%	0.0092	0.0295	+ 220.87%
Citation Counts	141,398	438,631	+ 210.21%	0.0108	0.0210	+ 48.52%

2.1 Innovation Intensity and Firm Size

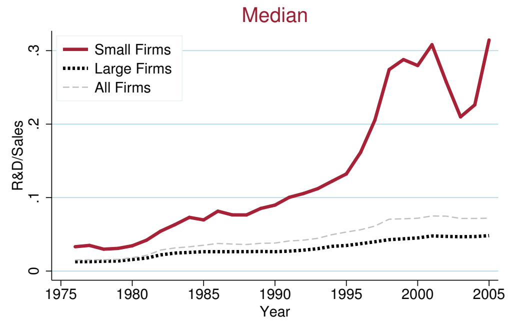
In this section, I discuss the relationship between innovation intensity and firm size and how this relationship has changed since the mid-1970s to the present. I use two distinct innovation measures: one constructed from data on research and development (R&D) expenditures from public firms' annual income statements, and another using data on granted patents. I document that using both measures:

1. Innovation activity has become increasingly concentrated among small firms,
2. There has been a substantial increase in the innovation intensity among small firms (but a much smaller increase among large firms), and
3. The relationship between firm size and innovation intensity has become increasingly negative.

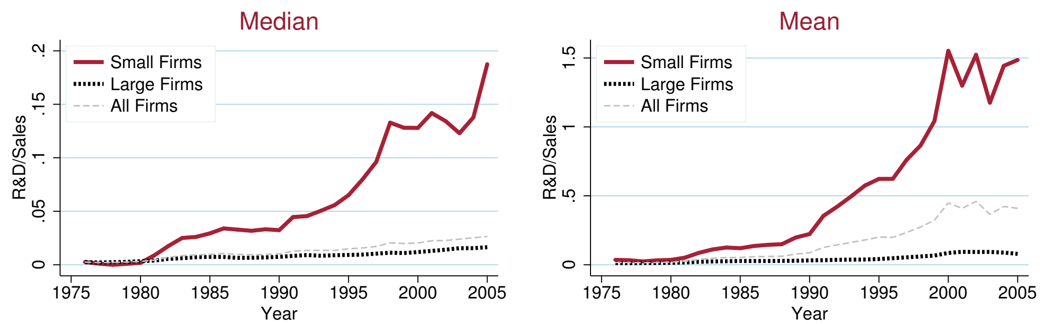
To illustrate the first two facts, I define small firms as those with less than $25 million[9] in annual sales. Table 2.1 provides evidence for the first stylized fact. As discussed in the previous section, the share of firms which I define as small has increased throughout the period, rising from 24 percent in 1980 to 29 percent in 2000. However, the increase in the share of R&D expenditures and citation-weighted patents attributed to these firms has increased disproportionally more than the number of firms in the sample. In particular, R&D expenditure and patent count shares of small firms more than doubled, whereas citations-weighted patent share increased by 50 percent.

The second fact in this section is illustrated in Figure 2.1. Here, I plot the mean and median R&D intensity, defined as annual R&D expenditures divided by annual sales, for small and large firms over the period 1976-2005. There was a surge of firms with very low sales entering the sample in the 1990's, which would drive up the R&D intensity measures of small firms as sales enter in the denominator of this measure. To make sure that these trends are robust, I exclude all firms with annual sales under $1 million in these plots. Including these firms would drive up the magnitude of

[9]In 2000, approximately 30% of listed manufacturing firms had under $25 million in annual sales.



(a) Excluding Zero and Missing Observations



(b) All Missing Observations Replaced With Zeros

Figure 2.1: R&D Intensity Trends. Sample includes all domestic manufacturing firms with annual (real) sales exceeding \$1 mil and coverage in Compustat. Small firms are those with less than \$25 million in (real) annual sales. The top panel plots the cross-sectional median and mean R&D/Sales for small and large firms with missing and zero R&D expenditure observations excluded. The bottom panel plots the cross-sectional median and mean R&D/Sales for small and large firms including zero observations for R&D expenditures and replacing all missing observations with zeros.

the increase in R&D intensity of small firms. An additional issue with this measure arises as a result of SEC guidelines for reporting R&D expenditures on companies' financial statements. A firm is supposed to report R&D expenses if they are deemed "material" by the accountant. As a result, there may be observations with missing entries even though a firm may have incurred small positive R&D expenditures throughout the year. To address the problem of excluding these observations from the computation of R&D intensities, I replace all the missing R&D expenditures with zeros to get a lower bound for these trends. The results are reported in Figure 2.1b. The finding that small firms experienced a significant rise in R&D intensity over the period as compared to larger firms is maintained even with this adjustment. It is important to note, that these trends are qualitatively robust to changes in the sales cutoff for small firms and the definition of firm size[10]. Please see Appendix A for additional evidence of increased patenting among small firms.

To analyze the change in the the relationship between R&D intensity and firm size, I run the following cross-sectional regression in each year:

$$\ln(R\&D_{i,t}/Sales_{i,t}) = \beta_0 + \beta_1 \ln(Sales_{i,t-1}) + \delta_j + \varepsilon_{i,t} \quad (1)$$

[10]For example, the median R&D intensity of firms with less than 100 employees rose from 0.04 to 0.4, compared to an increase from 0.02 to 0.06 for other firms.

where i denotes a particular firm and δ_j are industry fixed effects. A regression coefficient β_1 close to zero will signify that R&D expenditures scale proportionally to firm size in the sample. This coefficient is plotted in Figure 2.2a. It becomes apparent that while it was the case that R&D scaled up close to proportionally to sales in the past, a 10 percent increase in sales nowadays is associated to only around a 7 percent increase in R&D expenditures. To put this is perspective, according to these results, a small firm (one which is at the 10th percentile of the sales distribution) is allocating 13.5 percent to R&D expenditures in 2000 relative to the median firm' expenditures, whereas in the late 70's, it would only allocate 6 percent. In Appendix A, I present further evidence to support this fact. In particular, I show that these trends are robust to including firm fixed effects and controlling for compositional changes in the sample over time. I also demonstrate that there has been a negative trend when considering the extensive margin of the innovation decision, i.e. the probability that the firm is actually conducting R&D in a given period has become increasingly disassociated with how large the firm is.

To explore the trends in the relationship between citation-weighted patents and firm size, I run the following reduced form poisson regression in each year:

$$Citations_{i,t} = \exp\left(\beta_0 + \beta_1 \ln(Sales_{i,t}) + \delta_j + \varepsilon_{i,t}\right) \tag{2}$$

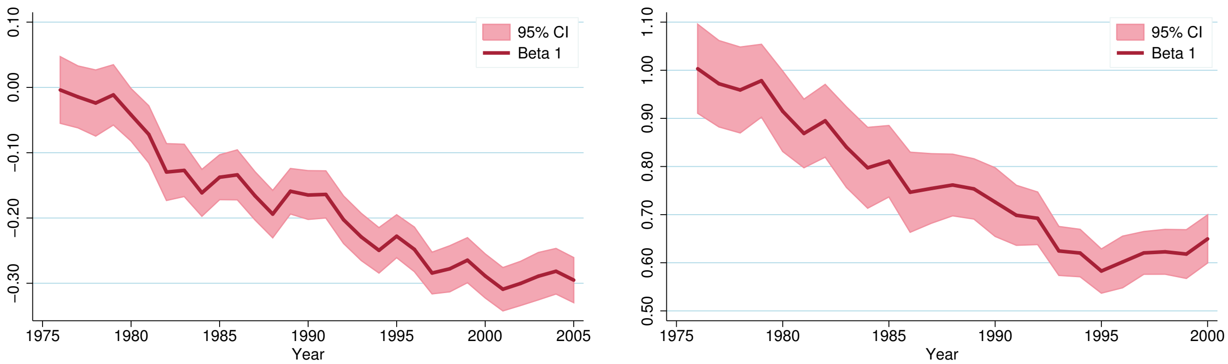
where $Citations_{i,t}$ denote the total forward citations received by a firm for patents which it applied for in year t and δ_j are industry fixed effects. Similar to R&D intensity, the relationship between citation-weighted patents and firm size has decreased as can be observed in Figure 2.2b. Whereas in the past, a 1 percent increase in sales was associated with in increase of 2.7 in citation-weighted patents, this decreased to 1.9 in the more recent periods. These result imply that a small firm (10th percentile of the sales distribution) will acquire approximately 13.2 percent of citation weighted patents in 2000 relative to the median firm, whereas in the late 70's, it will acquire only 9.2 percent.

2.2 External Equity Financing and Firm Size

In this section, I discuss the trends in the relationship between equity financing intensity and firm size. External equity financing is defined as the firms' annual net proceeds from stock issuance and referring to intensity simply means scaling that value by a measure of firm size (sales, in this case). I use both, data from the cash-flow statements of firms in the Compustat and the information from SEC filings regarding the primary share[11] proceeds in the SDC database for the firms in my sample. In the next section, I discuss why equity financing (and not debt financing) is the relevant source of external financing for firms pursuing innovation activity. I document that using both sources:

1. There has been a substantial increase in the equity financing intensity among small firms (but with a much smaller increase among large firms), and

[11] Firms have an option to issue new, primary shares, or they can offer existing shares of common stock, secondary shares. Only primary share issuances lead to capital inflows to the firm.



(a) R&D Intensity and Firm Size

(b) Citation-Weighted Patents and Firm Size

Figure 2.2: Innovation Regression Results. Figure in the left panel plots the estimated coefficient $\hat{\beta}_1$ from the cross-sectional regression 1. Figure in the right panel plots the estimated coefficient $\hat{\beta}_1$ from the the cross-sectional poisson regression 2. Variables have been Winsorized at the 1 percent level and standard errors are robust to heteroskedasticity and within-firm serial correlation in both specifications. Patent citation analysis does not extend past year 2000 due to citation truncation problems in the patent data.

2. The relationship between firm size and equity financing intensity has become increasingly negative.

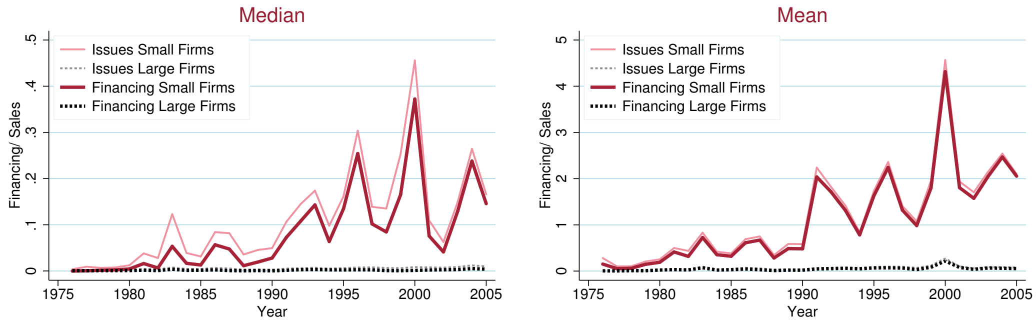
Similarly to the previous section, I first plot the mean and median equity financing intensity for small and large firms over the period 1976-2005. These results are reported in Figure 2.3. The rise in small firm financing from equity issues is striking, increasing from essentially negligible in 1970's to multiples of annual sales. There is a noticeable difference in the magnitudes of these trends between the two datasets[12]. One difference comes from lack of stock repurchase information in the SDC database. Fama and French (2005) note that the difference in these two datasets can also come from the missed employee option exercises in the SDC database, which are accounted for in the cash-flow statements of these firms. In the estimation of the model in Section 4, I do not explicitly target equity financing.

To analyze the change in the the relationship between equity financing intensity and firm size, I run the following reduced form regression in each year:

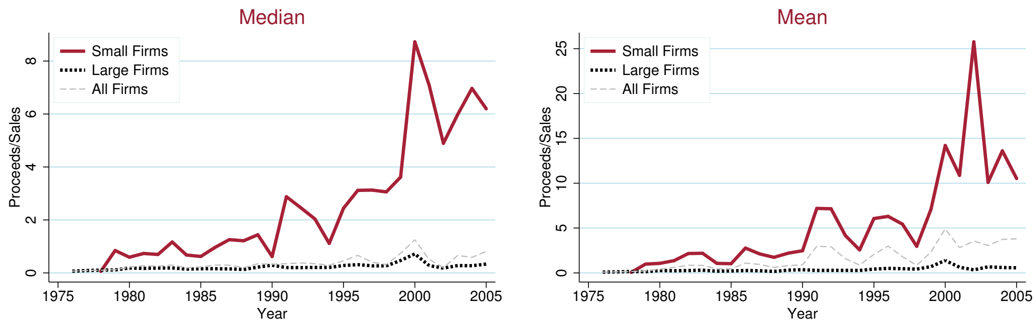
$$\ln(Equity\,Financing_{i,t}/Sales_{i,t}) = \beta_0 + \beta_1 \ln(Sales_{i,t-1}) + \delta_j + \varepsilon_{i,t} \tag{3}$$

where the variables on the right-hand side are as in the regression formulation 1. The β_1 coefficient is plotted in Figure 2.4. The regression results from the Compustat tell us that a small firm (10th percentile of the sales distribution) is raising 32 percent in equity on average in 2000 relative to the median firm, whereas in the late 70's, it would only raise 7 percent on average.

[12]In Appendix A, I decompose these trends in increases in proceeds from IPOs and SEOs.



(a) From Firm Financial Statements - Compustat



(b) From SEC Filings - SDC database

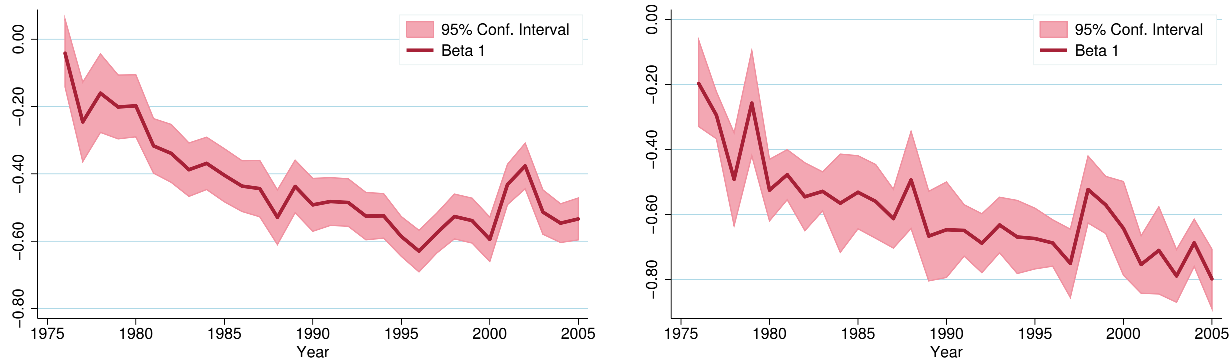
Figure 2.3: Equity Financing Intensity Trends. Sample includes all domestic manufacturing firms with annual (real) sales exceeding $1 mil and coverage in Compustat. Small firms are those with less than $25 million in (real) annual sales. Both panels plot the cross-sectional median and mean Equity Financing/Sales for small and large firms. For the top panel, the equity financing measure is defined as the proceeds from the net sale of stock taken from the firms' cash flow statements in the Compustat. For the bottom panel, the equity financing measure is defined as the proceeds from primary share issuance in the SDC database. Figure A.8 decomposes the trends in the bottom panel into trends in the IPOs and SEOs.

Unlike equity financing, small firm financing from debt has not increased for the median firm. I also observe a strong downward trend in small firms' internal financing, or cash flows[13]. I provide evidence for both of these findings in Appendix A.

2.3 Innovation Intensity and Firm Financing

Having established that small firms became increasingly innovative over time and have begun raising more funds through external equity, what remains to be shown is that these trends are related. In particular, the goal is to demonstrate that firms which do not generate sufficient funds internally raise external equity to be able to finance their R&D investment. I already noted in the previous section that mean and median cash flows (internal funds) that small firms in my sample generate have significantly decreased. In this section, I document the following fact: firms' R&D spending increases following issues of equity.

[13]Bates et al. (2009) document that public firm cash-holdings also rose, primarily among firms that do not pay dividends and those more recent IPO cohorts. Brown and Petersen (2011) and Lyandres and Palazzo (2012) study how this can come as a result of intertemporal smoothing of R&D expenditures. These findings are consistent with financially constrained firms raising funds through large equity issues and using them to finance subsequent R&D.



(a) Compustat

(b) SDC

Figure 2.4: Equity Financing Regression Results. Figures plot the estimated coefficient $\hat{\beta}_1$ from the cross-sectional regression 3 with data from the Compustat (left panel) and the SDC Platinum Database (right panel). Variables have been Winsorized at the 1 percent level and standard errors are robust to heteroskedasticity and within-firm serial correlation in both specifications.

The preference for equity finance over debt finance for innovative firms has been noted in several papers (Hall and Lerner (2009), Brown et al. (2009), Itenberg and Stangebye (2013)). The argument essentially relies on the following: 1) concave structure of a debt contract may not be appropriate for a project with volatile returns, 2) a significant part of the value created when innovation in undertaken is intangible, and hence non-collateralizable, and 3) adverse selection and moral hazard problems associated with innovation activity are magnified compared to capital investment. In fact, if I break the sample into innovative firms (those which on average allocate more than 5 percent of their sales to R&D expenditures) and the rest, I observe that innovative firm issue equity twice as often and the median firm raises approximately 60 percent of external funds from equity as compared to only 5 percent for noninnovative firms.

To further explore the relationship between proceeds raised from equity financing and subsequent R&D investment of the firms in my sample, I run the following reduced form regression:

$$\ln\left(\sum_{\tau=1}^{n}\frac{R\&D_{i,\tau}}{Sales_{i,0}}\right) = \beta_0+\beta_1\ln\left(\frac{Primary_{i,0}}{Sales_{i,0}}\right)+\beta_1\ln\left(\frac{Other_{i,0}}{Sales_{i,0}}\right)+\beta_3\ln\left(Sales_{i,0}\right)+\delta_t+\delta_j+\varepsilon_{i,t} \quad (4)$$

where the subscript $t = 0$ implies the period in which equity is raised, $\sum_{\tau=1}^{n} R\&D_{i,\tau}$ captures the total R&D expenditures in the following periods $t = 1$ to $t = n$, *Primary* denotes proceeds raised from the issuance of primary shares, *Other* includes proceeds from issuance of debt and cash flows generated by the firm at $t = 0$, and δ_t and δ_j are year and industry fixed effects respectively. The results in Table 2.2 indicate that the coefficients on primary capital raised in equity offerings are generally larger than the corresponding coefficients for the other sources of capital. These findings suggest that the funds raised equity issues are likely to be used for R&D expenditures than are internally-generated funds. The specification presented here is a variant of one used in Kim and Weisbach (2008) to study the reasons for equity issuance among firms from different countries

Table 2.2: Equity Financing and R&D. Sample includes all domestic manufacturing firms with positive annual (real) sales and coverage in Compustat and SDC in 1976-2005. Variables have been Winsorized at the 1 percent level and standard errors, clustered by issuer, are reported in the parenthesis. * $p < 0.05$, **$p < 0.01$, *** $p < 0.001$. *Primary* denotes proceeds raised from the issuance of primary shares and *Other* includes proceeds from issuance of debt and cash flows generated by the firm.

	(1) $n = 1$	(2) $n = 2$	(3) $n = 3$	(4) $n = 4$
$\ln(Primary\ Proceeds_0/Sales_{i,0})$	0.355***	0.409***	0.431***	0.446***
	(0.0389)	(0.0452)	(0.0450)	(0.0475)
$\ln(Other\ Sources_0/Sales_{i,0})$	0.0209	0.0385	0.0597*	0.0532
	(0.0241)	(0.0277)	(0.0291)	(0.0304)
$\ln(Sales_{i,0})$	-1.081***	-0.0809**	-0.06366*	-0.0607*
	(0.0231)	(0.0264)	(0.0266)	(0.0278)
Constant	-3.049***	-3.085***	-2.652***	-2.517***
	(0.304)	(0.484)	(0.523)	(0.546)
Industry	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Observations	2620	2471	2312	2147
R^2	0.83	0.37	0.37	0.39
Adj R^2	0.83	0.36	0.36	0.37

and also find a significant effect of equity issues (but a much smaller effect of debt and internally generated funds) on subsequent R&D expenditures.

2.4 Financial Changes From Late 1970's to 2000's

In this section, I briefly describe two financial changes which I hypothesize contributed to the increased innovation and equity financing of small firms since the late 1970's: 1) an evident decrease in the underwriting spreads associated with equity issues and 2) a decrease in effective marginal tax on corporate distributions.

In the study of equity and debt issues from 1970s to 2000s, Kim et al. (2003) find a gradual secular decline in median and mean underwriting spreads. More specifically, they find that mean underwriting spreads for SEOs fell by 16 percent from the 70's to the 90's and for IPO's, by 14 percent. Kim et al. (2008) attribute the fall in underwriting spreads over the period to the pro-competitive effect of the rise in commercial banks' participation in the securities underwriting business. The relevant deregulation for these changes is erosion and eventual repeal of the Glass-Steagall Act of 1933, which made it possible for commercial banks to underwrite securities through creating Section 20 subsidiaries. The authors finds that on average, commercial banks charge lower spreads of approximately 72 basis points for IPOs and 43 basis points for SEOs. They also document that as a result of commercial bank entry, IPO spreads dropped by 60 basis points in IPOs and SEO spreads dropped by 28 basis points.

Table 2.3: Underwriting Spread. The table reports the number of issues and median and mean underwriting spread for periods 1976-1985 and 1996-2005. Sample includes all IPO's and SEO's from the SDC database filed by manufacturing firms with coverage in the Compustat in these periods. Small firms are those with less than $25 million in (real) annual sales. Underwriting spread is computed by dividing the total amount paid to the underwriters by the total proceeds raised from share issuance.

	Number		Median		Mean	
	1976-1985	1996-2005	1976-1985	1996-2005	1976-1985	1996-2005
All Firms						
All Issues	1136	1639	0.074	0.064	0.072	0.063
IPOs	452	724	0.083	0.076	0.085	0.074
SEOs	684	915	0.063	0.054	0.067	0.056
Small Firms						
All Issues	325	523	0.099	0.069	0.095	0.066
IPOs	216	287	0.100	0.080	0.097	0.078
SEOs	109	236	0.089	0.060	0.092	0.057

Table 2.3 provides information regarding how the underwriting spreads changed for firms that issued equity in my sample. Clearly, underwriting spreads are higher for IPOs than SEOs both presently and in the past. The average gross spread paid on equity issues declined by approximately 14 percent, 13 percent for IPOs and 16 percent for SEOs, comparing the two periods. Interestingly, the decreases in underwriting spreads for small issuers are more drastic relative to the sample of all issuers.

The decline in effective marginal dividend tax was investigated by McGrattan and Prescott (2005). Using data from tax returns, they estimate that the effective tax rate on corporate distributions fell from an average 41 percent in 1970s to 17 percent in the 1990s. They attribute this fall to two changes: the fall in ordinary taxes[14] and the rise in the share of equity held by non-taxed entities, namely pension funds and retirement accounts. The latter change is of particular interest since it results from financial deregulation which alleviated restrictions placed on the types on investments fiduciaries could make. Prior to 1974, pension funds and retirements accounts had few guidelines regarding what constituted imprudent behavior and thus steered clear of holding equity, fearing the risk of being sued in case the value of the portfolio fell. Following the enactment of the Employment Retirement Income Security Act (ERISA), pension funds became regulated intermediaries, subject to uniform fiduciary standards. The clarification of these standards in 1979 essentially allowed pension managers to invest in high-risk assets. As a result of this deregulation, the percentage of corporate equity held by non-taxed entities rose from 4 percent in 1960 to 51 percent in 2000. With more equity in non-taxed or tax-deferred accounts, the effective tax rate on corporate distributions fell.

[14] Dividends paid out to shareholders are taxed as ordinary income. In 1964, the highest marginal income tax rate was reduced from 91 percent to 70 percent, followed by a drop to 50 percent in 1981 and a final drop to 28 percent.

3 Model

In order to quantitatively assess the contribution of financial changes discussed in the previous section on increased innovation and equity financing of small firms, I build a general equilibrium model of firm dynamics. In this section, I describe the features of the model and discuss its properties.

3.1 Preliminaries

The model presented in this section builds on Akcigit (2010). Time is discrete and indexed by $t = 0, 1, 2, \ldots$. There are 3 types of agents in this economy: households, final goods producers, and intermediate goods producers[15].

3.2 Households

The representative household maximizes the expectation of an infinite sum of discounted utility:

$$U_t = \mathbb{E}_t \sum_{t=\tau}^{\infty} \beta^{\tau} \left(\frac{C_{\tau}^{1-\sigma} - 1}{1-\sigma} \right) \tag{5}$$

where C represents the consumption of the final good, Y, $\beta \in (0, 1)$ is the discount factor, and $\mathbb{E}_t$ is the expectation operator conditional on the information available at time t.

The household income comes from wages, earned by supplying one unit of labor inelastically each period, and dividends on the shares of existing firms, which implies the following budget constraint:

$$C_t + \int_{i \in I_t} (v_{i,t} - D_{i,t}) s_{i,t} di \leq \int_{i \in I_{t-1}} \max\{v_{i,t}, \underline{v}\} s_{i,t-1} di + w_t + T_t \tag{6}$$

where I_t denotes the set of all active firms in the economy at time t, w_t is the wage and T_t is the lump-sum transfer of the aggregate dividend taxes collected. $D_{i,t}$ denotes after-tax dividend payout of firm i in the case that the payout is positive and equity issuance in the case that it is negative. For convenience, I assume that dividends are paid just after shares are bought. $s_{i,t}$ and $v_{i,t}$ denote the number of shares and the share price of firm i at time t respectively and $\underline{v}$ is the liquidation value that the household is paid on each share if the firm exits.

3.3 Final-Goods Producers

The final good, Y_t is produced by a continuum of perfectly competitive final goods producers using a continuum of differentiated intermediate goods indexed by $i \in I_t$ and a numeraire good according to the following production function:

[15]There is also implicitly a government in this economy that taxes firms and rebates the taxes lump-sum to the households. Since this government does not make any decisions, I abstract from explicitly calling it an agent.

$$Y_t = \left[y_{0,t} \int_{i \in I_t} y_{i,t} di - \frac{\gamma}{2} \int_{i \in I_t} y_{i,t}^2 di - \frac{\delta}{2} \left(\int_{i \in I_t} y_{i,t} di \right)^2 \right]^{\frac{1}{2}} \tag{7}$$

where y_0 is the numeraire good and $y_{i,t}$ denotes the quantity of the variety i in time t.[16] The parameters γ, $\delta > 0$ dictate substitution patterns between the varieties and the numeraire good. These preferences feature a "love for variety" and therefore, in equilibrium, all varieties will be used in the production of the final good. The price of the final good is normalized to 1 without loss of generality.

The numeraire good, y_0 is produced in an outside market and sold to the final goods producer at a price $p_{0,t}$. Each variety, y_i, is produced by a sole monopolist $i \in I$ at and sold to the final goods producer at a price $p_{i.t}$. A monopolist i is capable of producing at most one variety.

The final goods producer seeks a bundle of the numeraire good and intermediate varieties, to maximize per-period profits. The problem of the representative final good producer is written as:

$$\pi_{Y,t} = \max_{y_0,\, [y_i]_{i \in I_t}} \left\{ Y_t(y_0,\, [y_i]_{i \in I_t}) - \int_{i \in I_t} p_{i,t} y_{i,t} di - p_{0,t} y_{0,t} \right\} \tag{8}$$

Solving the profit maximization problem, I obtain the final good producer's demand for the numeraire good is given by:

$$y_{0,t}^d = \left(\frac{1}{4p_{0,t}^2} + \frac{\delta}{2} \right) \int_{i \in I_t} y_{i,t} di + \frac{\gamma}{2} \frac{\int_{i \in I_t} y_{i,t}^2 di}{\int_{i \in I_t} y_{i,t} di} \tag{9}$$

The inverse demand for a particular intermediate firm's $i \in I$ product is thus given by:

$$p_{i,t} = \frac{y_{0,t} - \gamma y_{i,t} - \delta \int_{i \in I_t} y_{i,t} di}{2Y_t} \tag{10}$$

Therefore, the final good producers' demand for an intermediate good i is decreasing in its price, decreasing in the total output of all of the intermediate goods and increasing in the amount of the numeraire good purchased.

3.4 Intermediate-Goods Producers

This sector is composed of an endogenously determined mass of monopolistically competitive firms. The intermediate goods producers make production, R&D, and participation (entry and exit) decisions.

[16] A similar structure has been used by Ottaviano et al. (2002), Melitz and Ottaviano (2008), Corcos et al. (2007).

3.4.1 Production:

The output of the i^{th} firm follows a linear technology:

$$y_{i,t} = z_{i,t} l_{i,t} \tag{11}$$

where $l_{i,t}$ represents the labor input and $z_{i,t} \in [z_{\min,t}, \infty)$ is the firm-specific labor productivity at time t. The distribution of this productivity across firms, $\Psi_t(Z_t)$ is assumed to be bounded below by $z_{\min,t}$[17] to illustrate that some technologies may become obsolete. This productivity can be stochastically improved through investment in R&D. Using equation 11, firm's marginal cost can be written as $c_{i,t} = w_t / z_{i,t}$ where w_t is the wage rate. Improvements in firm-specific productivity are therefore going to result in the fall of the marginal cost of producing that variety.

The intermediate goods producer takes the wage, w_t, final good, Y_t, and the distribution of firm productivities, $\Psi_t(z)$, as given and chooses its price and quantity to maximize its per-period profit from operation subject to the demand of the final goods producer for variety i:

$$\begin{aligned} &\max_{p_{i,t},\, y_{i,t}} \left\{ (p_{i,t} - c_{i.t})\, y_{i,t} \;\middle|\; Y_t,\, w_t,\, \Psi_t \right\} \\ &\quad s.t. \;\; y_{i,t} = y^d_{i,t}(p_{i,t}) \end{aligned} \tag{12}$$

I define the relative firm productivity as, $\hat{z}_{i,t} \equiv z_{i,t}/w_t$. Marginal cost for the firm is thus $c_{i,t} = 1/\hat{z}_{i,t}$. The relative firm productivity is going to be the pay-off relevant state variable for the firm. Combining the decision of the intermediate goods producer and the demand for intermediate goods by the final goods producer, we can solve for the production and pricing decisions of the monopolist:

$$\begin{aligned} y_{i,t} &= \frac{Y_t}{\gamma} \left(\frac{2\gamma p_{0,t}}{N_t} + \overline{\left(\frac{1}{\hat{z}}\right)_t} - \frac{1}{\hat{z}_{i,t}} \right) \\ p_{i,t} &= \frac{1}{2} \left(\frac{2\gamma p_{0,t}}{N_t} + \overline{\left(\frac{1}{\hat{z}}\right)_t} + \frac{1}{\hat{z}_{i,t}} \right) \end{aligned} \tag{13}$$

where $N_t \equiv \int_{i \in I_t} di$ is the measure of firms in the economy and $\overline{(1/\hat{z})_t} \equiv (1/N_t) \int (1/\hat{z}_{i,t})\, di$ is the average marginal cost among operating firms. The resulting price charged by the monopolist is increasing in the marginal cost, but the resulting mark-ups are decreasing.[18] In addition, the price and the resulting mark-ups are going to be decreasing in the measure of firms.

Using the expressions for price and quantity produced from 13, the expression for intermediate firm's profit can be rewritten as:

[17] I assume that $z_{\min,t} = \hat{z}_{\min} w_t$.

[18] This characteristic is supported by empirical findings from Campbell and Hopenhayn (2005), Syverson (2004, 2007).

$$\pi_{i,t} = \frac{Y_t}{2\gamma}\left(\frac{2\gamma p_{0,t}}{\alpha N_t} + \overline{\left(\frac{1}{\hat{z}}\right)_t} - \frac{1}{\hat{z}_{i,t}}\right)^2 \tag{14}$$

Intermediate firm's profits will increase with improvements in its own productivity through the reduction in the marginal cost relative to the average marginal cost. A crucial feature of this model is that profits are concave in $\hat{z}_{i,t}$, resulting in diminishing returns in productivity improvements.

The intermediate firm is also going to be forced to pay out a fixed cost of operation in each period, $\varphi_{i,t}$. For reasons explained below, it will be useful to define the fixed cost as $\varphi_{i,t} = \hat{\varphi}_i Y_t$ and have it grow with the economy. The internal funds (cash-flows) that the firms will thus generate in each period will be the profits from production net of the fixed cost:

$$CF_{i,t} = \pi_{i,t} - \varphi_{i,t} \tag{15}$$

3.4.2 R&D Investment

Each intermediate good i has a quality ladder along which firm i improves its labor productivity $z_{i,t}$ through additive step-by-step innovations. Improvements in labor productivity reduce the marginal costs of production, holding wages constant. Outcome of R&D activity is uncertain and firms can only choose the probability with which they successfully innovate, $x_{i,t} \in [0, \overline{x}]$, $\overline{x} < 1$.

A firm's productivity evolves according to the following:

$$z_{i,t+1} = \begin{cases} z_{i,t} + \lambda_t & \text{with probability } x_{i,t} \\ z_{i,t} & \text{with probability } (1 - x_{i,t}) \end{cases} \tag{16}$$

where the step grows with the wage in the economy, $\lambda_t = \hat{\lambda} w_t$ and $\hat{\lambda}$ is fixed.[19] This formulation assumes constant returns to scale in quality improvements. This feature paired with the concavity of firm's profit in the firm-level productivity will generate greater incentives for firms with lower quality to innovate as compared to firms with higher quality.

In order to generate a probability of success $x_{i,t}$, the firm must employ $h_{i,t} = h(x_{i,t})$ scientists where $h'(x) \geq 0$, $h''(x) \geq 0$, $h(0) = 0$, $h(1) = \infty$. Therefore, the R&D costs of a firm choosing the success probability $x_{i,t}$ is given by $w_t h(x_{i,t})$.

Since the payoff-relevant productivity is $\hat{z}_{i,t} = z_{i,t}/w_t$, along with improvements resulting from innovation efforts, firm's state is also going to change with the changes in the equilibrium wage rate.

[19]In addition to choosing probability of success, I can also allow the firms to choose the size of the innovation step. This addition, although interesting and empirically relevant (there is a great heterogeneity among patents with regard to forward patent citations received, breadth, and originality) it is currently outside of the scope of this model.

D. Costly External Finance:

If the monopolist generates positive cash-flows in any given period, $CF_{i,t} > 0$, it may choose to allocate these funds to R&D expenditures and/or pay them out as a taxed dividend payment, $D_{i,t} = (1 - \tau_d)d_{i,t}$, where $d_{i,t} > 0$ and τ_d is the dividend tax rate. If the cash-flows generated in each period are not sufficient to cover the cost of conducting R&D or are negative, the firm will need to raise funds externally through equity issuance. Issuing stock is costly. Adopting the method in Gomes (2001), I summarize the costs of external finance with the following form:

$$\xi(z_{i,t},\, x_{i,t}) = \xi(w_t h_i(x_{i,t}) - \pi(z_{i,t})) \tag{17}$$

The function ξ has the following properties:

$$\xi(a) = 0 \text{ if } a \leq 0;\ \xi(a) > 0 \text{ if } a > 0;\ \xi'(a) > 0 \text{ if } a > 0 \tag{18}$$

Therefore, firms will only need to pay an equity issuance cost if their net issuance is positive and the costs are going to be increasing in the size of the issuance.

Presence of costs of issuance and dividend taxes implies that it will never be optimal for firms to pay out dividends and issue equity at the same time. Therefore, the only firms which will be issuing equity in this model are those who must out of necessity (because they have generated negative cash flows in a given period) and those who wish to spend on innovation an excess of what they can afford to using their internal funds alone.

E. Free Exit:

All firms have an outside option of of $\Lambda_t = \nu_\Lambda Y_t$ with $\nu_\Lambda \in (0,\, 1)$. The firms may decide to exit once the stochastic innovation outcome is realized. The decision to exit is denoted by $\kappa_{i,t} = 1$.

F. Free Entry:

There is an outside pool of potential entrants. An entering firm is required to pay a fee $\chi_t = \nu_\chi Y_t$ with $\nu_\chi \in (0,\, 1)$. If a firm decides to enter, it draws its productivity from the last period's end-of-period productivity distribution $\Psi_{t-1}(Z_t)$. A given firm will enter the market as long as the expected value of entry exceeds the entry cost, χ_t. The process of entry will act to pin down the equilibrium measure of firms in the economy, N_t.

G. Timing:

The timing of intermediate firm's decisions are summarized in Figure 3.1. First, new firms pay the entry free, draw their productivity, enter the market and the equilibrium measure of firms is pinned down. Next, the final goods producer and the intermediate goods producers make the decisions regarding production and the profits and cash flows are realized. Following production,

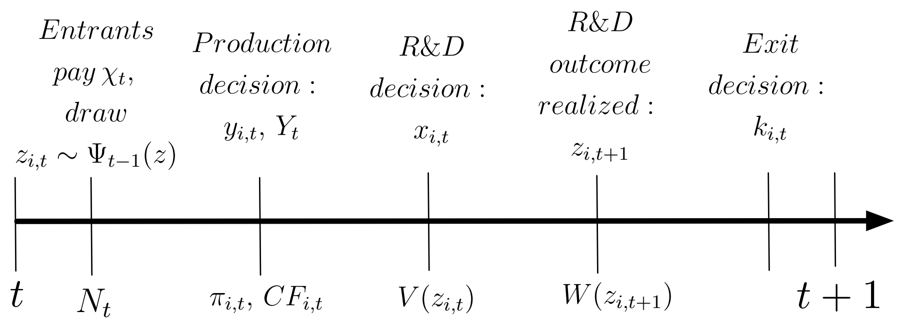


Figure 3.1: Timing

intermediate goods producers make the R&D decision, and either pay out dividends or issue costly external equity. Lastly, the success of R&D investment is realized and knowing their respective productivity for the next period, firms decide to stay active or exit.

H. Value Functions and Free Entry

Let $z_{i,t}$ be the productivity of firm i at time t and let $z_{i,t+1}$ be the productivity after the realization of the R&D outcome. The beginning and end-of-period Bellman equations for value of the firm, $V_t(\cdot)$ and $W_t(\cdot)$ respectively, will have the following formulation:

$$\begin{aligned} V_t(\hat{z}_{i,t}) &= \max_{x_{i,t}} \left\{ d_{i,t} - \mathbb{I}(d_{i,t} > 0)\tau_d d_{i,t} + \hat{\beta}_t \left[x_{i,t} W_t(\hat{z}_{i,t} + \hat{\lambda}) + (1 - x_{i,t}) W_t(\hat{z}_{i,t}) \right] \right\} \\ & \quad s.t. \\ & \quad d_{i,t} = \pi_t(\hat{z}_{i,t}) - \varphi_{i,t} - w_t h(x_{i,t}) - \xi(\hat{z}_{i,t},\, x_{i,t})) \end{aligned}$$

$$W_t(\tilde{z}_{i,t+1}) = \max_{\kappa_{i,t} \in [0,1]} \left\{ \kappa_{i,t} \Lambda_t + (1 - \kappa_{i,t}) V_{t+1} \left(\frac{w_t}{w_{t+1}} \tilde{z}_{i,t+1} \right) \right\}$$

where $\hat{\beta}_t < 1$ represents the firms' discount factor. To summarize, a firm with productivity $\hat{z}_{i,t}$ will generate cash flows $\pi_t(\hat{z}_{i,t}) - \varphi_{i,t}$ in a given period and will spend $w_t h(\phi_{i,t})$ for R&D in order for its productivity tomorrow to jump with probability $x_{i,t}$. If the remaining funds after R&D investment are positive, $d_{i,t} > 0$, the firm will pay out dividends for which it will incur a proportional tax of τ_d. On the other hand, if the remaining funds are negative, $d_{i,t} < 0$, the firm will issue equity and incur a floatation cost $\xi(\hat{z}_{i,t},\, \phi_{i,t})) > 0$. Once the outcome of the innovation is realized, $\tilde{z}_{i,t+1} = \hat{z}_{i,t} + \hat{\lambda}$ with probability $x_{i,t}$ and $\tilde{z}_{i,t+1} = \hat{z}_{i,t}$ with the complimentary probability, the firm can makes a decision to stay in operation or exit. If the firm decides to operate, it will enter the next period with the payoff-relevant productivity $\hat{z}_{i,t+1} = \frac{w_t}{w_{t+1}} \tilde{z}_{i,t+1}$, since the new marginal cost of the firm will not only reflect changes in it's own productivity, but also the growth in the wage rate. Therefore, if the firm is not successful in innovating in this period, it will start the next period with a lower effective adjusted productivity. If the firm is unsuccessful in innovating for a series of periods, its productivity may lower to a point at which it becomes "obsolete" ($\hat{z} < \hat{z}_{\min}$) and will exit.

Given the expression for the value function above, I can now discuss the free-entry condition in the economy. Firm will attempt to enter as long as the expected value of entry is higher than the entry cost:

$$\int V_t(z/w_t) d\Psi_{t-1}(z) \geq \chi_t \tag{19}$$

Suppose that the expected value of entry is greater than the entry fee. In that case, many firms will want to enter and the measure of firms, N_t will rise. It is clear from 14 that the profits of the monopolist are decreasing in the measure of firms, leading the value of operating a firm to decrease. This will lower the expected value of entry until expression 19 holds with equality. Therefore, the free-entry condition will act to pin down the equilibrium measure of firms in the economy.

3.5 Balanced Growth Path

I seek a stationary equilibrium in which all aggregate variables grow at the same rate g. In this pursuit, to transform the problem into a stationary one, it will be useful to normalize those variables which grow over time by Y_t. From here on, the transformed variables will be denoted as $\tilde{s} \equiv s_t/Y_t$. I can now define and characterize the steady-state equilibrium in this model.

Definition 1. (**Equilibrium**) A Balanced Growth Path equilibrium is a tuple:

$$\left\langle \boldsymbol{p}^*,\, \boldsymbol{y}^*,\, y_0^*,\, \mathbf{V},\, \mathbf{W}, \boldsymbol{x}^*,\, \boldsymbol{\kappa}^*,\, \hat{\boldsymbol{\Psi}}^*,\, N^*,\, \tilde{w}^*,\, g^*,\, \{C_t^*\}_{t=0}^{\infty} \right\rangle$$

such that:

i) $\boldsymbol{p}^*$, $\boldsymbol{y}^*$ are characterized by 13;
ii) y_0^* is characterized by 9;
iii) $\mathbf{V}$, $\mathbf{W}$ satisfy the monopolists beginning-of-period and end-of-period values;
iv) $\boldsymbol{x}^*$, $\boldsymbol{\kappa}^*$ solve the beginning-of-period and end-of-period value functions of the monopolist;
v) $\hat{\boldsymbol{\Psi}}^*$ forms an invariant distribution over the state space $\hat{Z}$;
vi) N^* is constant and is consistent with the steady-state free-entry condition;
vii) $\tilde{w}^*$ clears the labor market;
viii) C_t^* solves the household maximization problem;
ix) the aggregate variables Y_t, w_t, C_t and the average inverse firms' productivity, $\frac{1}{N^*}\int_{i\in I^*}\frac{1}{z_{i,t}}di$ grow at the steady state rate g^* which is consistent with the steady-state R&D choices $\boldsymbol{x}^*$.

In order to discuss the features of this equilibrium, I first rewrite the normalized value functions where tilde denotes a variable scaled by the final good, Y_t.

$$
\begin{aligned}
\tilde{V}(\hat{z}) &= \max_{x} \left\{ \tilde{d} - \mathbb{I}(\tilde{d} > 0)\tau_d \tilde{d} + \hat{\beta} \left[\phi \tilde{W}(\hat{z} + \hat{\lambda}) + (1 - \phi)\tilde{W}(\hat{z}) \right] \right\} \\
& \quad s.t. \\
& \quad \tilde{d} = \tilde{\pi}(\hat{z}) - \tilde{\varphi} - \tilde{w}h(x) - \tilde{\xi}(\hat{z},\, x) \\
\tilde{W}(\hat{z}) &= \max_{\kappa \in [0,1]} \left\{ \kappa \nu_{\Lambda} + (1 - \kappa)\tilde{V}\left(\frac{\hat{z}}{1+g} \right) \right\} \qquad (20)
\end{aligned}
$$

Proposition 1. ***(Properties of the Value Function)*** Consider the dynamic optimization problem of an individual firm. For any given steady-state values $\left(\hat{\boldsymbol{\Psi}}^*,\, N^*,\, \tilde{w}^*,\, g^*\right)$:

(i) The value function $\tilde{V}(\cdot)$ exists and is unique.
(ii) The value function $\tilde{V}(\cdot)$ is increasing.
(iii) Optimal policy function $x^*(\hat{z})$ exists and is continuous.

Proof. See Appendix. □

The normalized outside option is $\nu_\Lambda = \tilde{V}(\hat{z}_{\min})$ so that the distribution of normalized productivities of active firms is as before. The optimal steady-state exit decision is thus characterized by a cutoff rule:

$$
\begin{aligned}
\kappa^* &= \begin{cases} 1 & \text{if } \nu_\Lambda > \tilde{V}\left(\frac{\hat{z}}{1+g^*}\right) \\ 0 & \text{if } \nu_\Lambda < \tilde{V}\left(\frac{\hat{z}}{1+g^*}\right) \end{cases} \\
\kappa^* &\in [0,\, 1] \text{ otherwise} \qquad (21)
\end{aligned}
$$

Given the stationary R&D decisions of the intermediate goods producers, $\boldsymbol{x}^*$, I can derive the equilibrium growth rate in the economy:

$$
g^* = \left(\int_{i \in I^*} \frac{w^*}{z_i} di \right) / \left(\int_{i \in I^*} \frac{w^*}{x_i^*(z_i + \lambda) + (1 - x_i^*)(z_i)} di \right) - 1 \qquad (22)
$$

Proposition 2. ***(Household's Euler Equation)*** In equilibrium, $\tilde{v}_i = \tilde{V}(\tilde{z}_i)$ and $\hat{\beta} = \beta/(1+g^*)^\sigma$.

Proof. See Appendix. □

3.6 Welfare

Along the balanced growth path, I can express the sum of discounted utility in equation 5:

$$\begin{aligned} Welfare &= \sum_{t=0}^{\infty} \beta^t \left(\frac{\left(C_0(1+g^*)^t\right)^{1-\sigma} - 1}{1-\sigma} \right) \\ &= \frac{1}{1-\sigma} \left(\frac{C_0^{1-\sigma}}{1-\beta(1+g)^{(1-\sigma)}} - \frac{1}{1-\beta} \right) \end{aligned} \tag{23}$$

where C_0 represents household consumption at $t = 0$. The resource constraint in the economy, given by $C_t = Y_t - p_0 y_{0,t}$ and the production decisions of the intermediate goods producers, will imply the following:

$$C_0 = (1 - p_0 \widetilde{y}_0^*) \left[\frac{\widetilde{y}_0^*/2 - p_0 \left(\delta + 2\gamma/N^*\right)}{\tilde{w}^* \int_{i \in I^*} (1/z_{i,0})\, di/N^*} \right] \tag{24}$$

where the denominator in the bracketed term represents the initial average marginal cost in the economy.

This concludes the theoretical section of the paper. In the next section, I compute the steady state equilibrium and estimate the parameters of the model in this section.

4 Estimation

In order to quantitatively asses the effect of changes in dividend taxation and equity floatation costs on firms' innovation policies and firm dynamics, I estimate the parameters of the model presented in the previous section using generalized method of moments (GMM). In this section, I first briefly discuss the computation of the model. I then describe the estimation procedure and the fit of the model given the resulting parameter values.

In order to bring the model to the data, I adjust the model in three ways. First, I adopt the following specification of the R&D cost function:

$$h(x) = \eta x^{\alpha} \tag{25}$$

where $\eta > 0$ and $\alpha > 1$. Second, I impose the floatation costs to have the following form:

$$\xi = \begin{cases} \hat{\xi}\left(wh(x_i) - \pi(z_i)\right)^2 & if\ \tilde{w}h(x_i) \geq \pi(z_i) \\ 0 & otherwise \end{cases} \tag{26}$$

where $\hat{\xi} > 0$. That is, if the firm's cash flows generated in any given period are not sufficient in covering its chosen investment, it must pay an additional variable cost which depends on the square of the external equity financing raised. The convexity assumption is consistent with empirical evidence of rising marginal costs of issuing equity in Altinkilic and Hansen (2000). In addition, imposing the equity costs to be convex while the dividend tax is linear gives room for these two mechanisms to have differential effects in the model.

Lastly, since the presence of dividend taxation and floatation costs introduces kinks in the innovation policy functions, small changes in parameter values may lead to large jumps in model moments and cripple the estimation procedure. To address this problem, instead of having the fixed costs constant among the firms, I require the firms in the model to draw an i.i.d. fixed cost each period from a uniform distribution: $\varphi_{i,t} \sim U[\mu_\varphi - \varepsilon, \mu_\varphi + \varepsilon]$. Since this draw is i.i.d., this adjustment does not alter the dynamics of the model nor does it introduce another state variable. However, it is useful to adopt this formulation as to generate smooth policy functions in the aggregate when individual firms' policy functions may be kinked.

4.1 Estimation Procedure

Parameters in the model are estimated by the Generalized Method of Moments (GMM). For a given set of parameter values, the model will generate statistics that can be compared to the data targets. The parameter values are then chosen to minimize some weighted distance between the model statistics and the data targets. Let $d(\theta)$ be the difference between model moments and data moments for a set of parameters, θ. The estimation procedure solves the following problem:

$$\begin{aligned} \theta^* &= \arg\min_\theta D^2(\theta) \\ D^2(\theta) &= d(\theta)' W d(\theta) \end{aligned} \tag{27}$$

where W is a diagonal weighting matrix. Since the problem is generally nondifferentiable and may be discontinuous at certain points, I use a generalized pattern search algorithm to solve the problem given by 27.

The vector of the standard errors for the estimator θ^* is given by the square root of the diagonal of the following matrix:

$$V(\hat{\theta}) = \frac{1}{n} \left[d_1(\hat{\theta})' W d_1(\hat{\theta}) \right]^{-1} d_1(\hat{\theta})' W \Sigma W d_1(\hat{\theta}) \left[d_1(\hat{\theta})' W d_1(\hat{\theta}) \right]^{-1} \tag{28}$$

where Σ is the variance-covariance matrix of data moments, $d_1(\hat{\theta}) = \partial d(\hat{\theta}) / \partial \theta$, computed numerically, and n is the number of observations.

Using the procedure outlined above, I estimate the following 9 parameters:

$$\boldsymbol{\theta} = \left\{ \gamma,\, \delta,\, \eta,\, \alpha,\, \lambda,\, z_{min},\, \mu_\varphi,\, \varepsilon,\, \hat{\xi} \right\} \in \boldsymbol{\Theta}$$

where $\mathbf{\Theta}$ represents the set of feasible values for the parameters.

4.2 Computational Algorithm

In order to compute the model, I solve a nested fixed point problem. The general equilibrium variables in the model are: the growth rate g, the quantity and cost of the numeraire good, $\tilde{y}_0$ and p_0 respectively, the labor share, $\tilde{w}$, and the measure of firms, N. Given the values for these variables, I can solve for firms' equilibrium innovation decisions and the invariant distribution of firm productivities . Since the presence of dividend taxation and equity floatation costs introduces frictions into the problem and results in kinked value and policy functions, I choose to use value function iteration to solve for the value of the firm. I discretize the sole state variable in the model into 561 points and choose 33 points for possible fixed costs draws. The algorithm for solving the model numerically is as follows.

1. Start with an initial guess for the parameters $\theta_{guess} \in \Theta$, set $tol^D = \infty$.
2. Guess an initial value for aggregate equilibrium variables $S_{guess} = [g,\, \tilde{y}_0,\, p_0,\, \tilde{w},\, N]'_{guess}$.
3. Compute the value function, $\tilde{V}\,(\hat{z})$.
4. Generate innovation policy, $x(\hat{z})$.
5. Using $x(\hat{z})$, compute the invariant distribution of firms, $\mathbf{\Psi}(\hat{q})$.
6. Update the values $S_{new} = [g,\, \tilde{y}_0,\, p_0,\, \tilde{w},\, N]'_{new}$. If, $\|S_{guess} - S_{new}\| < tol^S$, move on to step 7. Else, update the guess, S_{guess} and return to step 3.
7. Compute the moments of the model and $D^2(\theta_{guess})$. If $D^2(\theta_{guess}) < tol^D$, set $\theta_{new} = \theta_{guess}$ and $tol^D = D^2(\theta_{guess})$. Return to step 2.
8. Repeat, steps 1-7 until the global minimum is reached.

4.3 Parameter Estimates

Model period is taken to be one year. The following parameters are chosen a priori. The discount factor, β, is set to 0.975 and the inverse of the intertemporal elasticity of substitution $\sigma = 2$. The entry fee ν_χ is set such that the total measure of firms in the benchmark computation of the model is 1. Estimating the value of the outside option, ν_Λ, relevant for the exit decision, is analogous to estimating the cut-off productivity at which firms decide to exit z_{min} and I adopt the latter approach. In the benchmark computation of the model, the tax rates are set to their average values during the 1996-2005 period. Information on dividend tax rates is from McGrattan and Prescott (2005). The remaining nine parameters, are estimated with the GMM procedure outlined above.

Computing Data Moments

The estimation procedure targets eleven moments focusing on the differences in innovation intensity, productivity, sales growth, and transition rates between small and large firms in addition to moments which capture firm financing behavior. Each of the moments is chosen to highlight the most important features of the model. In order to compute data moments, I use a subset of the data used to conduct the empirical analysis in Section 2. In particular, I focus on the sample domestic manufacturing firms in the Compustat from 1996-2005[20]. In addition, I make the following adjustments to the data in order to eliminate industry and year effects from the computation of the moments. First, I drop the top and bottom 5 percent of observations for firm sales, R&D intensity, firm growth, labor productivity, and external equity financing intensity and calculate the medians of the relevant variables. I then compute the deviation for each variable in question from the year/industry means and add these deviations back to their respective medians, resulting in observations centered around the median. Since I would like to target the differences between firms of different sizes in my estimation, I break the sample into two groups: 1) small firms - those in the bottom 30% of the sales distribution and 2) large firms - the remainder of the firms. The first six moment conditions match the mean R&D intensities, labor productivities, and firm growth rates within each size group. The next two moments match the mean yearly transition rates between these two groups among year/industry observations. The last three moments match mean fraction of firms which pay out dividends, the correlation between firm size and dividend payout, and the mean equity financing cost for the firms which issue equity, respectively. Therefore, I use a total of 11 moment conditions in the estimation of 9 parameters.

Identification

To ensure the existence of a unique global minimum of the objective function, $D^2(\theta)$, at the true value for the parameters, I must choose moments which are sensitive to changes in parameter values. Although all of the moments are jointly determined in general equilibrium and are thus affected by changes in parameters, those parameters which are associated with the costs of innovation and the step-size of innovation, (η, α, λ), act to pin-down the moments related to R&D intensity, firm growth and transition probabilities since these moments are highly sensitive to firms' changes in innovation policies. Similarly, parameters in the final good aggregator and the exit productivity cutoff, (γ, δ, $\hat{z}_{\min}$) primarily affect the moments related to labor productivity of large and small firms. The coefficient on the floatation costs, $\hat{\xi}$ is important to pin down the mean floatation costs for equity issuing firms. Lastly, the mean of the fixed costs draws , μ_{fc}, will act to change the amount of firms paying out dividends and the spread in these fixed costs draws, ε, will be important in pinning down the co-movement between firm size as measured by sales and the amount that the firm pays out in dividends.

[20] There are several reasons I choose this period for the estimation. One reason is that it will be convenient for me to compare the present economy to an economy with higher taxes and equity issuance costs in the counterfactual. Secondly, since my estimated model is in balanced growth, it is appropriate to use the more recent period during which R&D intensity measures seem to be a more stable than in the past.

Table 4.1: Parameter Values

Description	*Parameters*	*SE*
Set a priori:		
Discount Factor, β	0.975	—
IES, $1/\sigma$	0.500	—
Dividend Tax Rate, τ_d	0.160	—
Estimated:		
Final Good Production:		
Subs. between numeraire and varieties, γ	0.100	0.003
Subs. among varieties, δ	0.736	0.038
Intermediate Goods Production:		
Fixed Cost Mean, μ_φ	0.085	0.005
Fixed Cost Spread, ε	0.045	0.008
Research and Development:		
Multiplier in the R&D cost function, η	8.903	0.719
Exponent in the R&D cost function, α	1.867	0.001
Step Size of Innovation, λ	16.320	0.870
Exit, $\hat{z}_{\min}$	14.157	0.822
Equity Float Cost Coefficient, ξ	2.500	0.567
Total: 9 parameters to estimate		

4.4 Results

Parameter Estimates

Table 4.1 reports the values for the parameters resulting from the estimation routine outlined above and their respective standard errors.

Goodness of Fit

Table 4.2 shows the comparison between the data and model moments. The estimation procedure generates a relatively good fit for the majority of the moments and can replicate the salient characteristics of data. R&D intensity and firm growth rates are significantly larger for small firms both in the data and in the model. On the other hand, small firms have a lower labor productivity and this difference is higher in the model than in the data. The model is also able to generate a higher transition from small to large firms than the reverse similar to what is present in the data. Less than half of the firms pay out dividends and there is a positive although imperfect relationship between

Table 4.2: Moment Conditions for Estimation. Sample includes domestic manufacturing firms with positive (real) sales and coverage in the Compustat from 1996-2005. The targets are computing by first dropping the top and bottom 5 percent of observations for firm sales, R&D intensity, firm growth, labor productivity, and external equity financing intensity and calculating the medians of the relevant variables. Next, the deviation for each variable from the year/industry means are computed and added back to their respective medians, resulting in observations centered around the median. Small firms are those in the bottom 30% of the sales distribution and the large firms are the complement. The first six moment conditions match the mean R&D intensities, labor productivities, and firm growth rates within each size group. The next two moments match the mean yearly transition rates between these two groups among year/industry observations. The last three moments match mean fraction of firms which pay out dividends, the correlation between firm size and dividend payout, and the mean equity financing cost for the firms which issue equity, respectively. Therefore, I use a total of 11 moment conditions in the estimation of 9 parameters.

Targets (11)	*Data 1996-2005*	*Model*
*R&D Intensity, Small**	0.1190	0.1192
R&D Intensity, Large	0.0522	0.0516
*Labor Productivity, Small**	1.7276	1.2795
Labor Productivity, Large	2.0086	2.0908
*Firm Growth, Small**	0.0592	0.0515
Firm Growth, Large	0.0545	0.0438
Transition, Small → Large	0.1113	0.1436
Transition, Large → Small	0.0548	0.0669
Measure with Dividends > 0	0.4311	0.4435
Corr(Sales, Dividends)	0.3187	0.3076
Mean Eq. Issuance Cost	0.0630	0.0630
Non-targeted Moments		
*Equity Fin. Intensity Small**	0.2998	0.1969
Equity Fin. Intensity Large	0.0468	0.0798
Measure with Cash Flows > 0	0.8202	0.5567

the amount of dividends paid out and firm size.

In addition doing a good job at matching the mean R&D levels for different size groups, the model is actually able to generate a good fit for R&D intensities for a more fine breakdown of firm size. This can be seen in the first panel of Figure 4.1. Each point on the graph is the mean R&D intensity for the each 5 percent of the sales distribution for the data used in the estimation and the model.

Validation Tests

I validate our model in two ways. The first approach compares non-targeted moments and correlations with those observed in the data. The second approach compares the estimated parameters to the micro estimates in the literature. The model performs fairly well in both in both cases.

First, the model is able to generate some feature of the data with regard to use of internal and external funds in Table 4.2 . Although less firms in the model generate positive cash flows

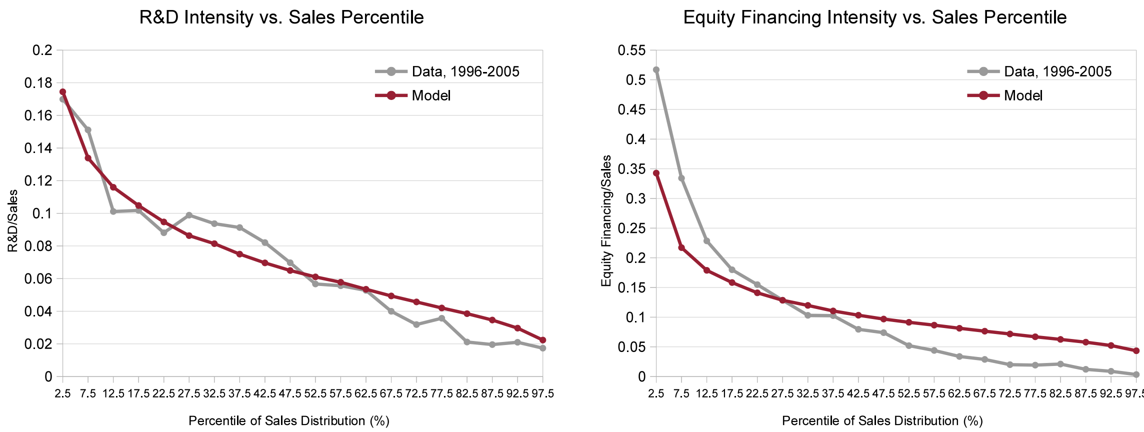


Figure 4.1: Benchmark R&D and Equity Financing Intensities. R&D and Equity Financing intensities are computed in the data once the adjustments described in Section 4.3 have been made. Both figures are constructing by taking the means of the respective variables for each 5 percent interval of the firm size distribution, sales in this case. The grey lines represent the values in the data and the red lines represent the model generated values. Only the mean R&D intensity for the bottom 30 percent and the top 70 percent of the sales distribution is targeted in the estimation.

as compared to those in the data, the model can replicate a greater external equity financing intensity among small firms as compared to large firms. In addition, the second panel of Figure 4.1 demonstrates that the model is able to replicate a general downward trend in external equity financing intensity over twenty firm size bins, but it it less steep than the relationship observed in the data. The model-generated equity financing intensities are lower than the ones observed in the data for small firms, but the reverse is true when looking at large firms.

The model can also qualitatively replicate the the correlations between firm size, R&D intensity, and equity financing intensity. These results are reported in Table 4.3a with 95 percent confidence bands in square brackets. The correlations of both R&D and equity financing intensities are negative, but are much more pronounced in the model than in the data. This is not surprising as the only two sources of heterogeneity among the firms in the model are their current productivity levels and the fixed cost draw.

The model seemingly generates no relationship between R&D intensity and equity financing intensity as compared to the positive relationship present in the data, but this number is misleading as there are two forces at play. On the one hand, fixing an operation cost draw, those firms which are more R&D intensive are also the ones which issue more external financing. On the other hand, fixing a firm size and comparing firms with different draws of operating cost, those firms with very high fixed cost draws, have to mechanically issue higher external equity and are less R&D intensive than similar firms which are not faced with a high fixed cost realization. This comes from the fact that for firms of the same size, the incentives to engage in innovation are the same, but the costs differ, i.e. using internal funds for R&D investment is effectively cheaper than issuing external equity. This feature is present in the data as can be seen from the positive relationship between

Table 4.3: Correlations - Model Benchmark. Sales, R&D and Equity Financing intensities are computed in the data once the adjustments described in Section 4.3 have been made. Table 4.3a reports estimated correlations along with the 95 percent confidence interval (in square brackets) for R&D intensity and sales, equity financing intensity and sales, and R&D intensity and equity financing intensity. Table 4.3b reports the correlations between R&D intensity and equity financing intensity for subsamples in the model depending on the fixed cost realization: 1) High (top 33.3 percent of the fixed cost distribution), 2) Medium (middle 33.3 percent of the fixed cost distribution), and 3) Low (lowest 33.3 percent of the fixed cost distribution).

(a) Firm Size, R&D Intensity and Equity Financing Intensity

	Data 1996-2005	*Model*
Corr(R&D Intensity, Sales)	-0.095 [-0.111, -0.080]	-0.811 [-0.813, -0.808]
Corr(EF Intensity, Sales)	-0.102 [-0.117, -0.086]	-0.487 [-0.492, -0.483]
Corr(R&D Intensity, EF Intensity)	0.364 [0.350, 0.378]	-0.005 [-0.011, 0.002]

(b) R&D and Equity Financing Intensity Relationship in Detail

Corr(R&D Intensity, EF Intensity)	*Model*
Fixed Cost - Low	0.440 [0.424, 0.456]
Fixed Cost - Medium	0.653 [0.641, 0.664]
Fixed Cost - High	0.740 [0.731, 0.749]

cash flows and R&D intensity, controlling for firm size. To further illustrate this point, I break down the model generated sample into three brackets according to the magnitude of the fixed costs draw and compute the correlations between R&D and equity financing intensities separately with these groups. As expected, Table 4.3b shows that within these groups, the relationship between R&D and equity financing is strongly positive.

The second validation test relies on comparing the estimated parameters from other estimates in the literature. In particular, the parameter α dictates the elasticity of innovation to R&D expenditures. In the estimation, $\alpha = 1.87$ which implies that the elasticity of the probability of innovating to R&D expenditures is $1/\alpha = 0.53$. In a previous empirical study, Griliches (1990) concluded that the elasticity of patents with respect to R&D is between 0.3 and 0.6 and Blundell et al. (2002) find this elasticity to be 0.5 using count data models. Therefore, the value estimated is consistent with the previous studies aimed specifically at estimating this relationship.

5 Counterfactual Experiments

Having estimated the parameters in model and analyzed the model fit for the period 1996-2005, I can now quantitatively evaluate the effect of changes in dividend taxation and equity floatation costs on innovation and financing behavior of firms of different sizes. In the first part of this section, I increase the dividend tax and equity floatation costs to their respective past levels in the period 1976 - 1985. The results of this experiment essentially show how different the environment would be today had the taxes and floatation costs not changed. Therefore, I can compare the model-generated firm policies to the data to assess how much of the trends outlined in Section 2, can be attributed to the changes in dividend taxes and equity floatation costs. This experiment is an appropriate way to asses the contribution of these two changes as there likely were other changes that have contributed to the differential innovation and financing behavior between the past and the present.[21]

5.1 Dividend Taxes and Equity Issuance Costs - Past Levels

The mean effective dividend tax rate for the period 1976-2005 is 41% (compared to the 16% in the later period) and the mean gross underwriting spread for the same period is 7.2% (compared to the 6.3% in the later period). I denote by (A) the results of the in the benchmark model, (B) the results of the model with only an increase in dividend tax and no change in equity floatation cost, and (C) the results of the model with both, an increase in dividend tax and equity floatation cost. When comparing the results in the data, I denote by (a) the results using the data from the period 1996-2005 and (b) the results using the data from the period 1976-1985.

Table 5.1 illustrates general features of how the model behaves when dividend taxes and equity floatation costs are changed. Increasing the dividend tax results in a lower growth rate and this effect is slightly heightened with an additional increase in the float cost. The firms which operate become larger on average than in the benchmark as can be seen from the increase in average sales and the measure of firms in operation decreases. In addition, firm profitability increase in the model from version (A) to (C). These feature is qualitatively consistent with the changes in the Compustat sample over the past 40 years, i.e. the negative relationship between then number of firms and firm profitability observed in Appendix A. Lastly, the share of scientists in the labor force rises and small firms account for a smaller portion of aggregate R&D expenditures.

In Table 5.2, I compare the changes in R&D and financing intensity for firms of different sizes. Overall, an increase in dividend taxation and equity floatation cost is responsible for a significant

[21] One significant policy change that occurred over the same period is the proliferation of both federal and state-level R&D tax credits. On the financing side, the state level banking deregulation and the development of venture capital funding possibly made it easier for firms to go public. For now, all of these other changes are outside of the scope of this model.

Table 5.1: Counterfactual Results. Table demonstrates some equilibrium results for: (A) the benchmark model, (B) model with only an increase in dividend tax and no change in equity floatation cost, and (C) model with both, an increase in dividend tax and equity floatation cost. Small firms are those in the bottom 30% of the sales distribution and the large firms are the complement. Aggregate profitability is defined as total profits divided by total revenues. Scientist share is defined as the total labor allocated to R&D activities divided by the the total labor supplied.

	(A) *Model* $\tau = 16\%$ $\xi = 6.3\%$	(B) *Model* $\tau = 41\%$ $\xi = 6.3\%$	(C) *Model* $\tau = 41\%$ $\xi = 7.2\%$	(A)→(C)
Growth	4.03 %	3.76 %	3.64 %	-9.68%
Measure of Firms	1.000	0.978	0.977	-2.30%
Average Sales	0.136	0.139	0.140	2.94%
Agg. Profitability	0.555	0.585	0.593	6.85%
Scientist Share	0.222	0.221	0.215	-3.15%
Small Firm R&D Share	49.19 %	48.05 %	48.02%	-2.38%

Table 5.2: R&D and Equity Financing Intensity by Firm Size Bracket. R&D and Equity Financing intensities are computed in the data once the adjustments described in Section 4.3 have been made. Small firms are those in the bottom 30% of the sales distribution and the large firms are the complement. The table reports R&D intensity and Equity Intensity for large and small firm brackets for: (a) Data 1996-2005 (estimation sample), (b) Data 1976-1985, (A) Model benchmark, (B) Model model with only an increase in dividend tax and no change in equity floatation cost, and (C) model with both, an increase in dividend tax and equity floatation cost.

	(a) *Data* *'96-'05*	(b) *Data* *'76-'85*	(a)→(b)	(A) *Model* $\tau = 16\%$ $\xi = 6.3\%$	(B) *Model* $\tau = 41\%$ $\xi = 6.3\%$	(C) *Model* $\tau = 41\%$ $\xi = 7.2\%$	(C)→(A)
*R&D Intensity, Small**	0.1190	0.0213	-81.10 %	0.1192	0.0967	0.0877	-26.43 %
R&D Intensity, Large	0.0522	0.0194	-62.84 %	0.0516	0.0446	0.0404	-21.70 %
*Eq. Fin. Intensity Small**	0.2998	0.0126	-95.80 %	0.1969	0.1491	0.1414	-28.19 %
*Eq. Fin. Intensity Large**	0.0468	0.0093	-80.13 %	0.0798	0.0766	0.0796	-0.25 %

drop in mean R&D intensity for both large and small firms. Consistent with the data, this drop is more pronounced for large firms than for small. Quantitatively, the model can explain approximately one-third of the R&D intensity difference between the past and the present. Changes in dividend taxation are responsible for most of this change. The model also generates a decrease in equity financing intensity of small firms and essentially no change in the intensity of large firms. In the data, on the other hand, there has been a drop in equity financing intensity among both firms, although greater for small firms. Figure 5.1 illustrates these changes for narrower bins of the sales distribution.

Comparing the relationship between firm size and policies, Table 5.3 shows that consistent with the data, the correlation between firm size and R&D intensity have become less negative as a result of an increase in tax and floatation cost. Similar change is observed for the correlation between firm

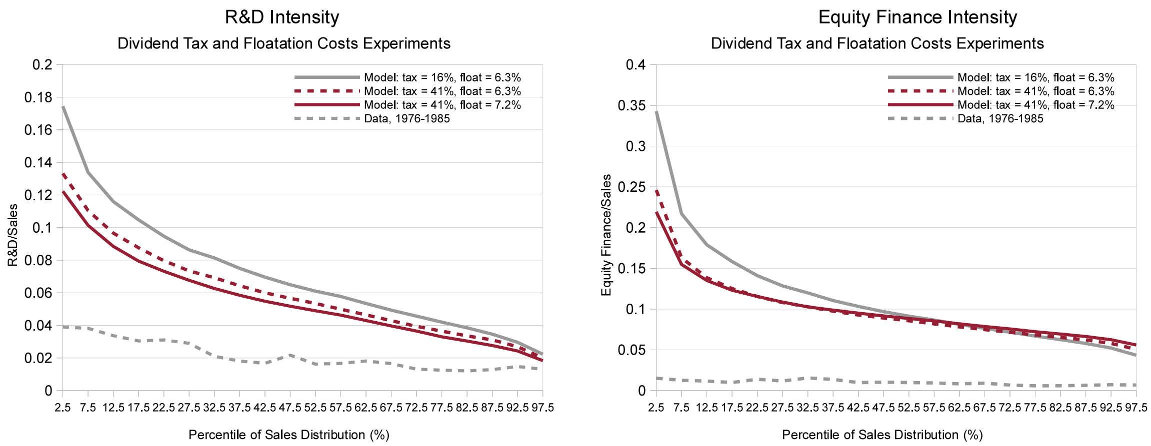


Figure 5.1: Changing Dividend Tax and Equity Floatation Costs. R&D and Equity Financing intensities are computed in the data once the adjustments described in Section 4.3 have been made. Both figures are constructed by taking the means of the respective variables for each 5 percent interval of the firm size distribution, sales in this case. The grey solid lines represent the model benchmark, the red dashed lines plot the model generated results once the dividend taxes are changed, the red solid lines plot the model generated results once the dividend taxes and the equity float costs are changed, and the grey dashed lines represent the data realizations for the period 1976-1985.

size and equity financing intensity.

Welfare Analysis

I normalize the welfare under the case of high dividend taxes and issuance costs to 100 and compute the welfare using equation 23. Note that in order to compute the welfare, I need to set the value of initial average inverse productivity and I choose $\int_{i \in I^*} (1/z_{i,0})\, di = 0.1$. Table 5.4 reports the welfare in each regime in consumption equivalent terms, i.e. how much of initial consumption C_0 would we have to take away in order for the benchmark to be as bad as the other regimes. The results say that the decrease in taxation and issuance costs results in a welfare improvement of 13.47 percent with the majority of it coming from the drop in taxes.

I then ask: how much of the change in welfare is due to the increased innovation of the part of small firms, "innovation" channel, versus the increase in the number of competitors and hence decreased markup distortions, "competition" channel? In order to quantitative answer this question, I rerun the economy in specification (C), but restrict the measure of firms from changing. Computing the new welfare under this alternative case, I find that the increase in welfare results primarily from the "innovation" channel, but the "competition" channel is also present, accounting for almost 9% in the increase in welfare.

Table 5.3: Counterfactual Experiments Correlations. Sales, R&D and Equity Financing intensities are computed in the data once the adjustments described in Section 4.3 have been made. Table 5.3a reports estimated correlations along with the 95 percent confidence interval (in square brackets) for R&D intensity and sales, equity financing intensity and sales, and R&D intensity and equity financing intensity for the data periods: (a) 1996-2005 (estimation sample) and (b) 1976-1985. Table 5.3b reports the same correlation measures for: (A) model benchmark, (B) model model with only an increase in dividend tax and no change in equity floatation cost, and (C) model with both, an increase in dividend tax and equity floatation cost. Table 5.3c reports the correlations between R&D intensity and equity financing intensity for subsamples in the model depending on the fixed cost realization: 1) High (top 33.3 percent of the fixed cost distribution), 2) Medium (middle 33.3 percent of the fixed cost distribution), and 3) Low (lowest 33.3 percent of the fixed cost distribution).

(a) Data

	(a) *1996-2005*	(b) *1976-1985*
Corr(R&D Intensity, Sales)	-0.095 [-0.111, -0.08]	-0.034 [-0.053, -0.015]
Corr(EF Intensity, Sales)	-0.102 [-0.117, -0.086]	-0.026 [-0.045, -0.007]
Corr(R&D Intensity, EF Intensity)	0.364 [0.350, 0.378]	0.075 [0.057, 0.094]

(b) Model

	(A) $\tau = 16\%$, $\xi = 6.3\%$	(B) $\tau = 41\%$, $\xi = 6.3\%$	(C) $\tau = 41\%$, $\xi = 7.2\%$
Corr(R&D Intensity, Sales)	-0.811 [-0.813, -0.808]	-0.559 [-0.563, -0.555]	-0.540 [-0.545, -0.536]
Corr(EF Intensity, Sales)	-0.487 [-0.492, -0.483]	-0.348 [-0.354, -0.343]	-0.298 [-0.304, -0.293]
Corr(R&D Intensity, EF Intensity)	-0.005 [-0.011, 0.002]	-0.358 [-0.363, -0.352]	-0.415 [-0.420, -0.410]

(c) Model - R&D and Equity Financing Intensity Relationship in Detail

Corr(R&D Int., EF Int.)	(A) $\tau = 16\%$, $\xi = 6.5\%$	(B) $\tau = 41\%$, $\xi = 6.5\%$	(C) $\tau = 41\%$, $\xi = 7.5\%$
Fixed Cost - Low	0.440 [0.424, 0.456]	0.158 [0.139, 0.177]	0.138 [0.118, 0.157]
Fixed Cost - Medium	0.653 [0.641, 0.664]	0.134 [0.115, 0.153]	0.009 [-0.011, 0.029]
Fixed Cost - High	0.740 [0.731, 0.749]	0.603 [0.591, 0.616]	0.510 [0.495, 0.524]

Table 5.4: Welfare. The table shows welfare in consumption equivalent terms computed using 23, 24, and setting $\int_{i \in I^*} (1/z_{i,0})\, di = 0.1$ for (A) model benchmark, (B) model model with only an increase in dividend tax and no change in equity floatation cost, and (C) model with both, an increase in dividend tax and equity floatation cost. Welfare in the case (C) has been normalized to 100. In order to decompose the change in welfare from (C) to (A) into the "innovation" channel, increased innovation of the part of cash constrained firms, and "competition" channel, increased number of competitors and hence decreased markup distortions, I restrict the measure of firms to be the same in both cases.

	(A) $\tau = 16\%$ $\xi = 6.3\%$	(B) $\tau = 41\%$ $\xi = 6.3\%$	(C) $\tau = 41\%$ $\xi = 7.2\%$
Welfare	113.47	103.33	100.00
Decomposing (C)→(A):			
Competition	8.98 %		
Innovation	91.02 %		

6 Conclusion

Motivated by novel empirical trends documented in U.S. public firm financial and patent data, I use a macroeconomic model of firm dynamics to quantify the effect of the decrease in the tax on corporate distribution and a drop in equity issuance cost on the rise in innovation activity and external equity financing among small manufacturing firms. I find that as a result of these two changes, the model generates: 1) one third of the observed increase in innovation intensity among small firms; 2) a 50 percent decrease in the correlation between firm size and innovation intensity; and 3) a 30 percent increase in external equity use among small firms. In addition, growth in the economy rises by 39 basis points and welfare increases by 13 percent in consumption-equivalent terms.

This paper could serve as a launchpad for several potential avenues of future research. One obvious next step is to explore the allocation of innovation activity for different sized firms at the cross-country level and see if this relationship is sensitive to the development in equity markets. I think it would also be interesting to explore the substitution between bank financing and venture capital for small start-up firms as opposed to public firms.

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A Appendix: Data

A.1 Data Sources

In order to conduct the empirical analysis to follow, I construct a dataset consisting of an unbalanced panel of public manufacturing[22] firms between the years 1976-2005, drawing information from three sources: S&P Compustat, NBER Patent Database, and SDC Global New Issues Database. Table A.1 provides some of the summary statistics for the dataset. All nominal variables are adjusted by the GDP deflator in the corresponding year and expressed in millions of 2005 U.S. dollars. Definitions and construction of the data items used in the empirical analysis are outlined in Appendix A.2. What follows is the description of these data sources.

Standard and Poor's Compustat Database: The S&P Compustat North America files contain financial statements for publicly traded firms from 1950's until the present day. I restrict my analysis to domestic[23] manufacturing firms which appear in the dataset between the years 1976 and 2005[24]. From this database, I use firms' annual income, balance sheet, and cash flow statements to gather information on industry, firm size, R&D expenditures, internal and external financing, and dividend payout. I drop observations for which sales are nonpositive.

One point that is worth discussing is that the sample of Compustat firms is one subject to selection bias and thus has changed significantly over the period in focus. Figure A.1 illustrates this point. The first panel shows that the number of firms has varied throughout the sample period. Of particular interest is the surge in IPO activity in the early 1990's and its subsequent drop.[25] The second panel illustrates how the composition of firms have changed over time across a subset of the most prominent sectors in the sample. An example of such a shift is the sharp increase in the share of firms in the Chemicals industry, mostly driven by the rise of Drugs (SIC 283) manufacturers. The last panel shows how the size distribution changed over time. The distribution of sales seems to have gotten more dispersed, with a higher fraction of small firms in the sample. Throughout the empirical analysis section, I will explore how these compositional changes affect the stylized facts.

NBER Patent Database: The NBER Patent Database contains information on all utility patents granted by the United States Patent and Trademark Office (USPTO) in the period 1976-2006. A patent is a type of intellectual property which gives its owner monopoly rights to commercialize an invention in exchange for public disclosure. A patent in the database includes

[22]Manufacturing firms are those with the two-digit SIC codes between 20-39. The majority, between 77 to 83 percent depending on the year, of R&D expenditures among domestic listed firms were conduced by firms in manufacturing.

[23]Domestic is defined as having headquarters in the United States.

[24]I start the sample in 1976 because that is the starting year for the NBER patent data. In addition, the Financial Accounting Standards Board issued a uniform reporting standard for R&D expenditures in June 1974 and starting my sample in 1976 ensures consistency in the R&D measures. I end the analysis in 2005 as I would like to abstract from effects of the financial crisis in 2008.

[25]Conventional wisdom has been that this occurred due to Sarbanes-Oxley Act of 2002 (SOX) which has imposed high compliance costs on publicly traded firms. Gao et al. (2013) attribute this drop instead to changing incentives of small firms to become acquired by a larger firm as opposed to operate individually due to decreased profitability of these types of firms.

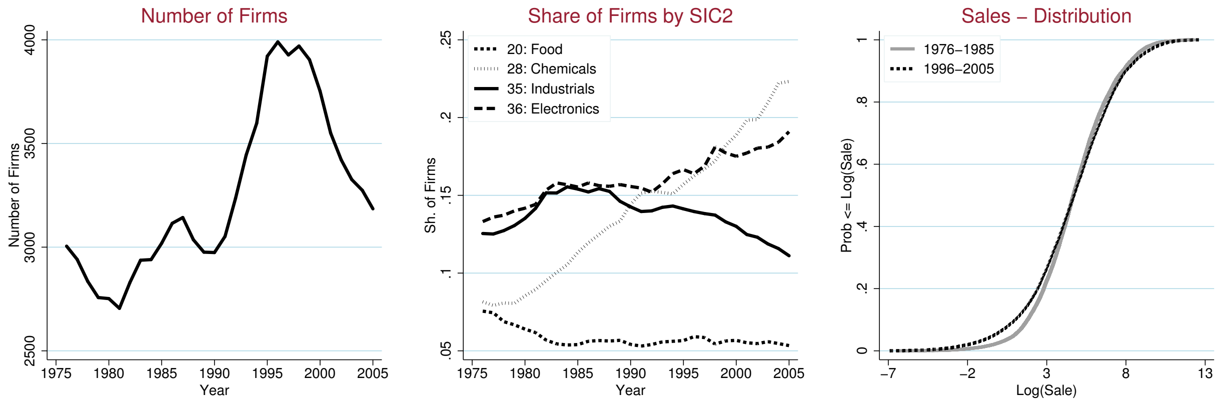


Figure A.1: Compustat Sample. Sample includes all domestic manufacturing firms with positive sales and coverage in Compustat. The panels illustrate some changes in the composition of this sample over time: 1) change in the number of firms, 2) change in the relative size of most prominent sectors, and 3) change in the firm size distribution.

information about characteristics of the inventor, the technology class of the innovation and the number of legal claims which are covered by the patent. In addition, it is possible to link patents through citations and for each patent compute statistics regarding forward citations[26], which can be used to proxy for patent quality. A detailed description of this dataset can be found in Hall et al. (2001). I use the application year as the relevant date for the patent as it corresponds more closely to when the innovation was actually created and developed. Since there is usually a time lag between when the patent is applied for and when it is granted, there is a truncation issue in the sample of granted patents. An example of this could be a patent which was applied for in 2004 but not granted until 2007. Although this patent should be included in the empirical analysis, it is missing from the patent data. In addition, forward citations of patents granted later on in the period are subject to the truncation bias described in Hall et al. (2001). To mitigate these issues, I restrict the data to the period 1976-2000 when looking at patent statistics.

A crucial feature of this database is the match to Compustat, which allows me to construct patent portfolios for those public manufacturing firms that were granted a patent in this period. I use the subset of observations from this database which are matched to the sample of Compustat firms.

SDC Global New Issues Database: The third dataset I use is the Thompson's Securities Data Corporation (SDC) Global New Issues database. This database provides information on total proceeds and the number of primary and secondary shares offered for each Initial Public Offering (IPO) and Seasoned Public Offering (SEO) from 1970 to present. Secondary shares differ from primary shares in that they are existing shares held by insiders and thus they are "non-dilutive". Since only primary shares lead to capital inflows to the firm, and thus can be used to finance investment, I focus only on those observations in which primary shares are offered. In addition to having information regarding amounts of shares offered and proceeds raised, SDC Global New

[26]Forward citations are defined as the number of subsequent patents which cite a particular patent. Backward citations are defined as the number of previous patents a particular patent cites.

Issues also contains information regarding the directs costs of issuance, the underwriting costs.

Similar to the NBER patent database, I only use a the subset of observations from SDC which I can match to the sample of Compustat firms through security identifiers.

A.2 Definition and Construction of Data Items

- $Assets_t$: Book assets (item 6) in period t .
- $Sales_t$: Sales (item 12) in period t.
- $R\&D_t$: Research and development expenditures(item 46) in period t.
- $Capx_t$: Capital expenditures (item 128) in period t.
- $Cash\,Flows_t$: Gross cash flows in period t are defined as (after-tax) income before extraordinary items (item 18) in period t plus depreciation and amortization (item 14) in period t plus research and development expenses (item 46) in period t.
- $Equity\,Issues_t$: Equity issues in period t is defined as the sale of common and preferred stock (item 108) in period t.
- $Equity\,Financing_t$: Equity financing in period t is defined as the sale of common and preferred stock (item 108) in period t minus the purchase of common and preferred stock (item 115) in period t. Alternative definition of equity financing used is the change in the book value of equity (item 216) between period t and $t-1$ minus change in the balance-sheet item for (accumulated) retained earnings (item 36) between period t and $t-1$.
- $Debt\,Financing_t$: Debt financing in period t is defined as the long-term debt issuance (item 111) in period t minus long-term debt reduction (item 115) in period t. Alternative definition of debt financing used is the change in total liabilities (item 181) between period t and $t-1$.
- $Debt\,Issues_t$: Debt issues in period t is the long-term debt issuance (item 111) in period t.
- $Dividend_t$: Dividend in period t is defined as dividends on preferred shares (item 19) in period t plus dividends on common shares (item 21) in period t.
- $Sales\,Growth_t$. : Sales growth in period t is defined as sales (item 12) in period t minus sales in period $t-1$ divided by sales in period $t-1$.
- $Acquisitions_t$: Acquisitions in period t is taken from the statement of cash flows (item 129).
- $OIBD_t$: Operating income before depreciation in period t (item 13).
- $Firm\,Age_t$: Firm age in period t is defined as the number of years from when the firm first appeared in the Compustat to period t.
- $Gross\,Spread/\,Underwriting\,Spread$: Gross spread or underwriting spread is defined as the total fees paid to the underwriters divided by the total proceeds from share issuance.
- $Cite_t$: Forward citation for a particular patent are defined as the number of future patents citing it. The citation count is adjusted by a weight to correct for truncation as derived in Hall et al. (2001).
- $Claim_t$: The claims in the patent specification outline the property rights protected by the patent and define the novel features of the invention.

A.3 Summary Statistics

Table A.1: Summary Statistics. This table presents the summary statistics for the sample of public manufacturing firms with positive annual sales and coverage in Compustat 1976-2005. All nominal variables are adjusted by the GDP deflator in the corresponding year and expressed in millions of 2005 U.S. dollars.Variable definitions and constructions is described in Appendix A.2.

Dataset	Variable	Obs	Mean	St Dev
Compustat	*Firm Size*			
	Log(Sales$_t$)	97,515	4.569	2.618
	Log(Assets$_t$)	97,460	4.614	2.373
	Log(Employment$_t$)	88,435	-0.358	2.236
	Investment			
	Log(R&D Expenditures$_t$)	61,976	1.563	2.295
	Log(Capital Expenditures$_t$)	94,730	1.457	2.687
	Financing			
	Log(Cash Flows$_t$)	77,110	2.836	2.336
	Log(Equity Issuance$_t$)	61,157	0.398	2.711
	Log(Equity Financing$_t$)	50,627	0.368	2.699
	Log(Debt Issuance$_t$)	52,567	2.186	2.718
	Log(Debt Financing$_t$)	33,071	1.915	2.595
	Log(Dividend$_t$)	42,765	1.650	2.526
	Other			
	Firm Age	97,515	14.132	12.154
	Unique Firms	9,245	—	—
NBER Patent Database (matched)	Citations	496,936	16.493	25.248
	Claims	496,936	16.051	13.193
	Unique Firms	4,035	—	—
SDC Platinum (matched)	Primary Stock Issues - Total	4,516	61.316	124.623
	Primary Stock Issues - IPO	2,113	51.044	109.184
	Primary Stock Issues - SEO	2,403	70.349	136.150
	Gross Spread - Total	4,516	0.070	0.021
	Gross Spread - IPO	2,113	0.081	0.016
	Gross Spread - SEO	2,403	0.061	0.021
	Unique Firms	3,080	—	—

A Appendix: Additional Empirical Facts

A.1 Additional R&D Facts

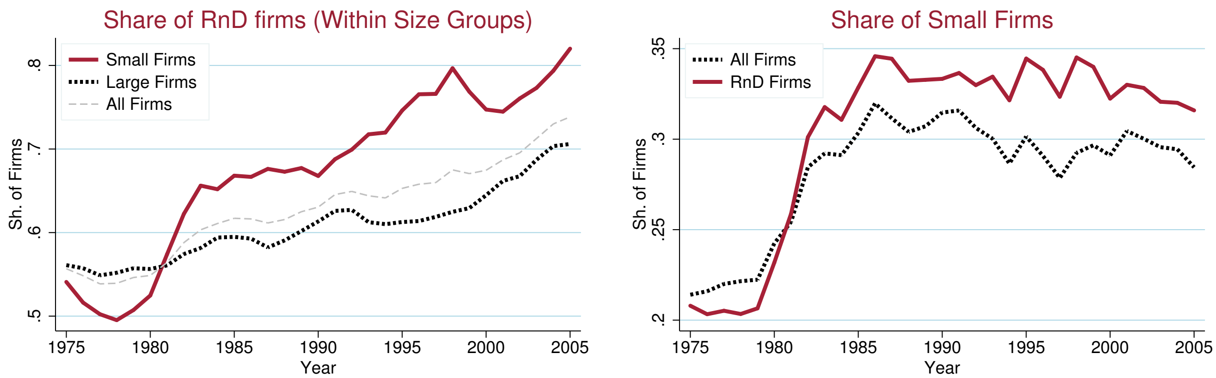


Figure A.1: Additional R&D Facts: Extensive Margin. Sample includes all domestic manufacturing firms with positive annual (real) sales and coverage in Compustat. Small firms are those with less than $25 million in (real) annual sales. The left panel plots the share of small (or large) firms that reported positive R&D expenditures out of all small (or large) firms in the sample. The right panel plots the share of small firms in the whole sample of firms and the share of small firms if the sample is restricted to only those firms which report positive R&D expenditures.

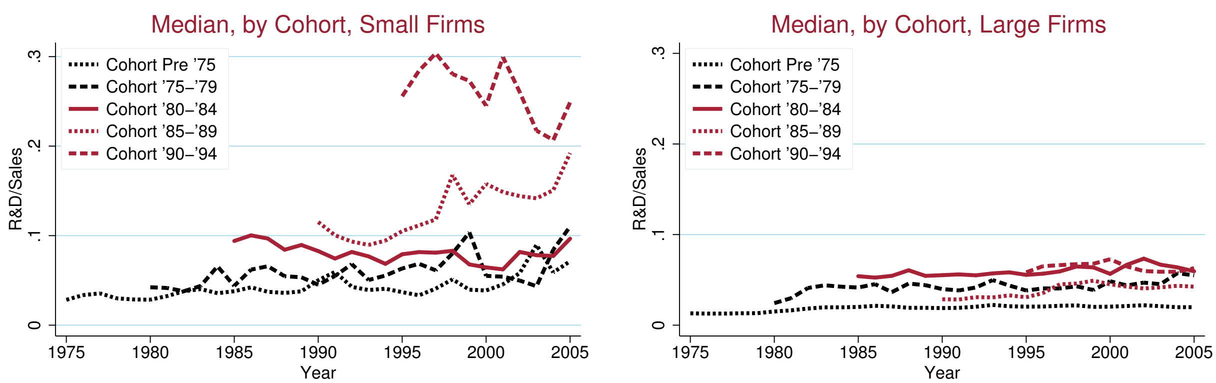


Figure A.2: Additional R&D Facts: IPO Cohort R&D Intensity. Sample includes all domestic manufacturing firms with annual (real) sales exceeding $1mil and coverage in Compustat. Small firms are those with less than $25 million in (real) annual sales. The left panel plots the small firms' cross sectional median R&D/Sales for firms in different IPO cohorts. The right panel plots the same statistic for large firms.

A.2 Additional Patent Facts

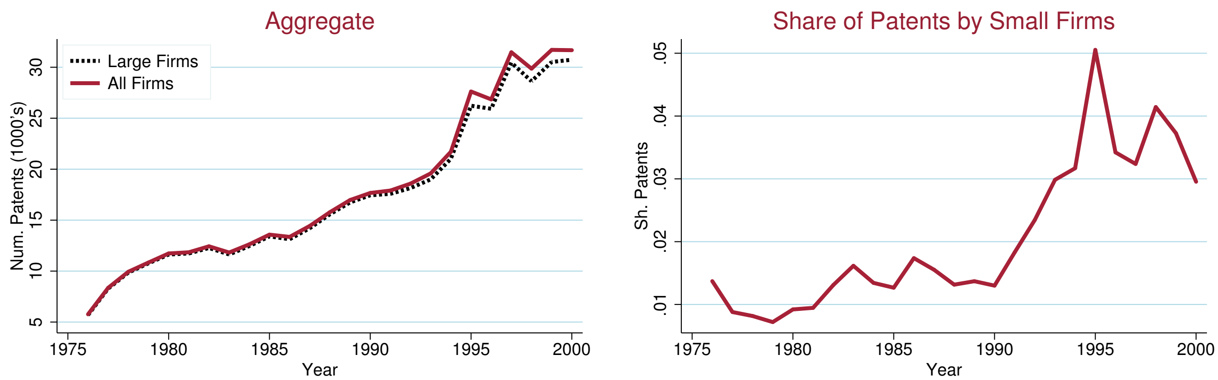


Figure A.3: Additional Patent Facts: Aggregates. Sample includes all domestic manufacturing firms with positive annual (real) sales and coverage in Compustat. Data on patents is from the NBER patent database. Small firms are those with less than $25 million in (real) annual sales. The left panel plots total patents and total patents acquired by large firms. The right panel plots the share of patents out of all patents acquired by small firms.

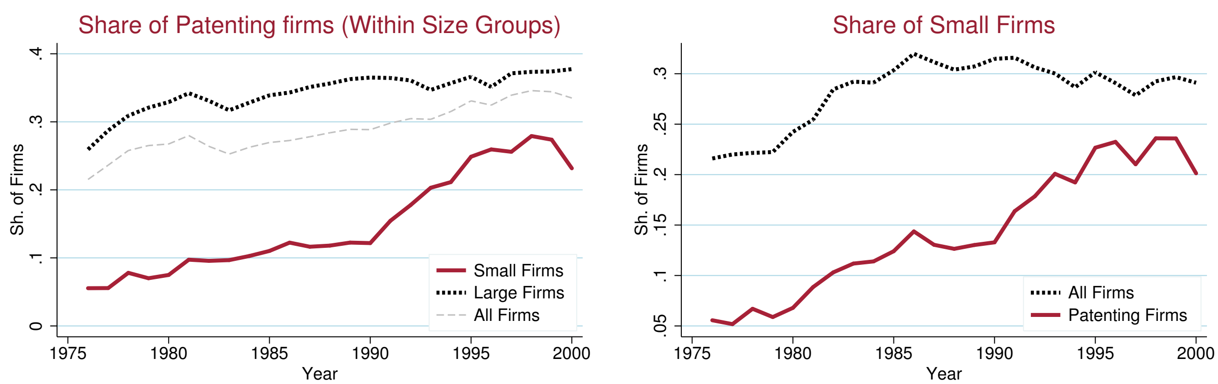


Figure A.4: Additional Patent Facts: Extensive Margin. Sample includes all domestic manufacturing firms with positive annual (real) sales and coverage in Compustat. Data on patents is from the NBER patent database. Small firms are those with less than $25 million in (real) annual sales. The left panel plots the share of small (or large) firms that were granted a patent out of all small (or large) firms in the sample. The right panel plots the share of small firms in the whole sample of firms and the share of small firms if the sample is restricted to only those firms which were granted a patent.

A.3 Additional R&D Intensity and Firm Size Regressions

Table A.1: Additional R&D and Firm Size Regressions. Sample includes all domestic manufacturing firms with positive annual (real) sales and coverage in Compustat in 1976-2005. Variables have been Winsorized at the 1 percent level and robust standard errors are reported in the parenthesis. * $p < 0.05$, **$p < 0.01$, *** $p < 0.001$. The regressions include only observations in years 1976-1985 and 1996-2005 and *Current* denotes any year after 1996. The first column shows the coefficient for the standard OLS regression. The second column includes firm-level fixed effects. The third column runs logit specification. All regressions are meant to show that there is a negative relationship between R&D intensity and firm sales and this relationship has become more pronounced in the more recent period (coefficients highlighted in red).

$$\ln\left(R\&D\,Intensity_{i,t}\right) = \beta_0 + \beta_1 \ln\left(Sales_{i,t-1}\right) + \gamma_0 Curr. + \gamma_1 \ln\left(Sales_{i,t-1}\right) \times Curr. + \delta_j + \delta_t + \varepsilon_{i,t}$$

	(1) **OLS**	(2) **FE**	(3) **R&D > 0**
$Log(Sales_{t-1})$	-0.120*** (0.00554)	-0.192*** (0.0102)	0.221*** (0.00684)
$Log(Sales_{t-1}) \times Current$	**-0.225*** (0.00734)**	**-0.127*** (0.00826)**	**-0.0991*** (0.00951)**
Constant	-3.792*** (0.176)	-2.714*** (0.157)	-0.973*** (0.261)
Current, Year	Yes	Yes	Yes
Sector	Yes	No	Yes
Year/Sector	Yes	Yes	Yes
Observations	36,477	36,477	57,952
R^2	0.505	0.906	

$$\ln(R\&D_{i,t}/Sales_{i,t}) = \beta_0 + \beta_1 \ln(Sales_{i,t-1}) + \delta_j + \varepsilon_{i,t}$$

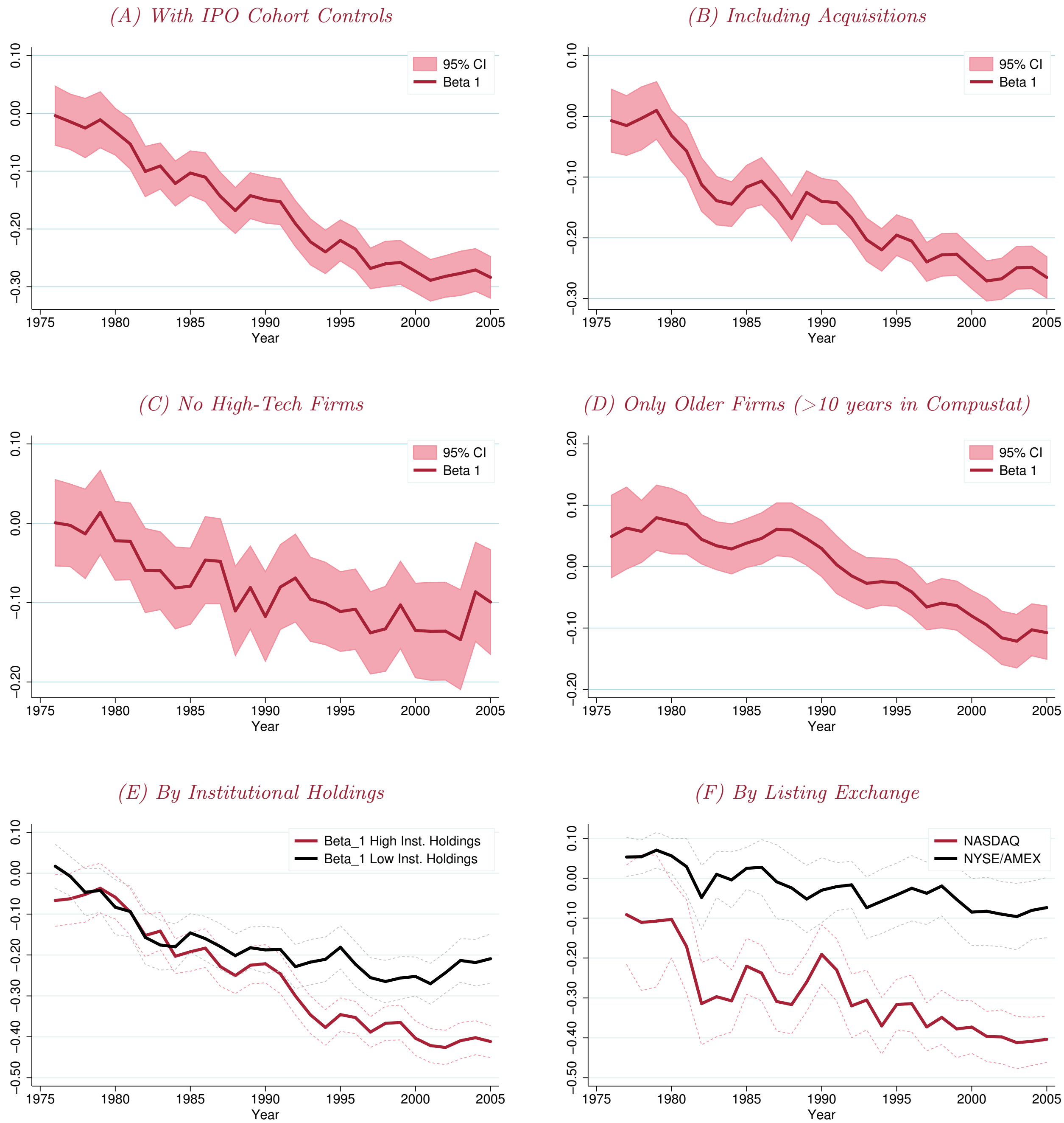


Figure A.5: Alternative R&D Intensity Regressions. Figures plots the estimated coefficient $\hat{\beta}_1$ from the cross-sectional regression 1 with some modifications. Variables have been Winsorized at the 1 percent level and standard errors are robust to heteroskedasticity and within-firm serial correlation in all six specifications. Panel (A) includes additional controls for the IPO cohort for each firm. Panel (B) adds the acquisitions reported by the firm in the statement of cash flows to the R&D measure. This is done in order to check the robustness of the results in the case that large firms have simply reallocated their resources from R&D activity to instead acquiring assets of other innovative firms. Panel (C) excludes high tech firms from the sample where high-tech is defined as in Brown et al. (2009). Panel (D) includes only firms who have been in the Compustat for longer than 10 years to verify that the trends are not solely driven by recently IPO'd firms. Panel (E) separates the sample into two groups by industry: 1) those industries whose institutional holding is above 30 percent and the complement. Panel (F) separates the sample into two groups depending on which exchange the firm is listed.

A.4 Profitability Trends

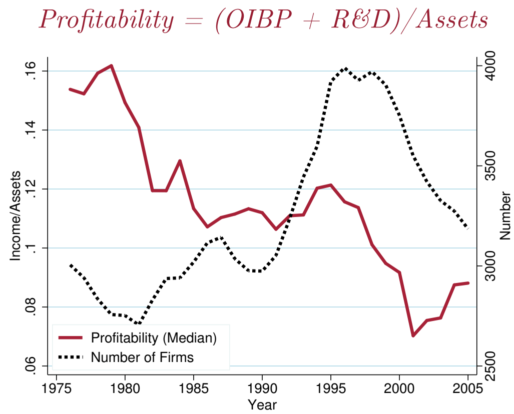
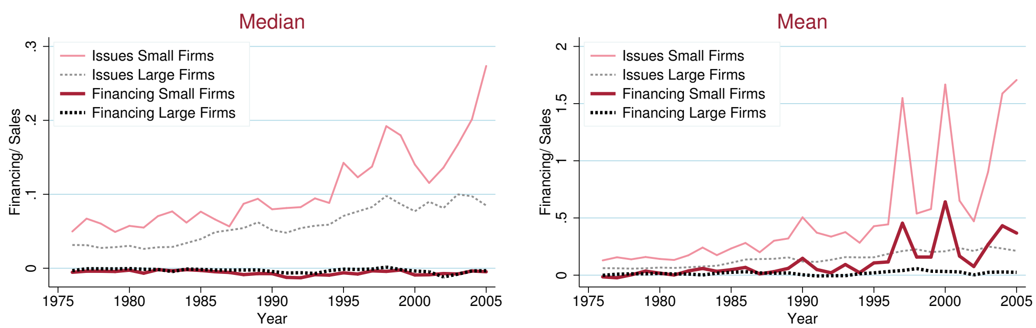
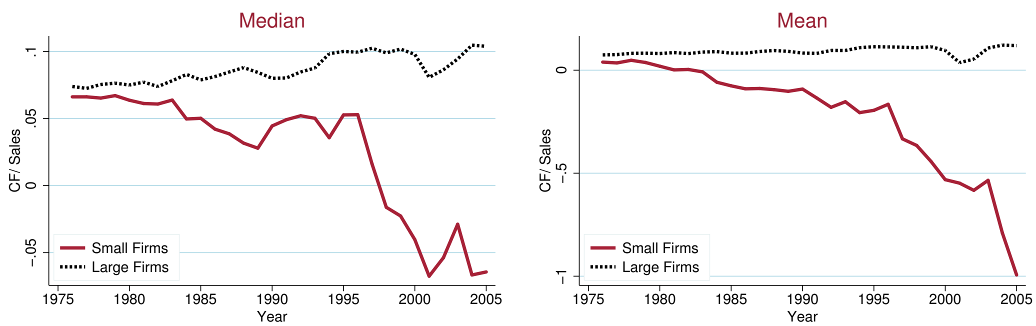


Figure A.6: Number of Firms and Profitability. Sample includes all domestic manufacturing firms with positive annual (real) sales and coverage in Compustat. Figure plots the total number of firms in the sample and the median firm profitability for those firms. R&D is added back to operating income before depreciation to get a measure of the income the firm generates period to making R&D investments.

A.5 Additional Firm Financing Facts



(a) Debt Financing/Sales



(b) Cash Flows/Sales

Figure A.7: Debt Financing and Cash Flows. Sample includes all domestic manufacturing firms with annual (real) sales exceeding $1 mil and coverage in Compustat. Small firms are those with less than $25 million in (real) annual sales. Top panel plots the cross-sectional median and mean Debt Financing/Sales for small and large firms. Bottom panel plots the cross-sectional median and mean Cash Flows/Sales for small and large firms. Construction of debt financing and cash flows measures is described in Appendix A.2.

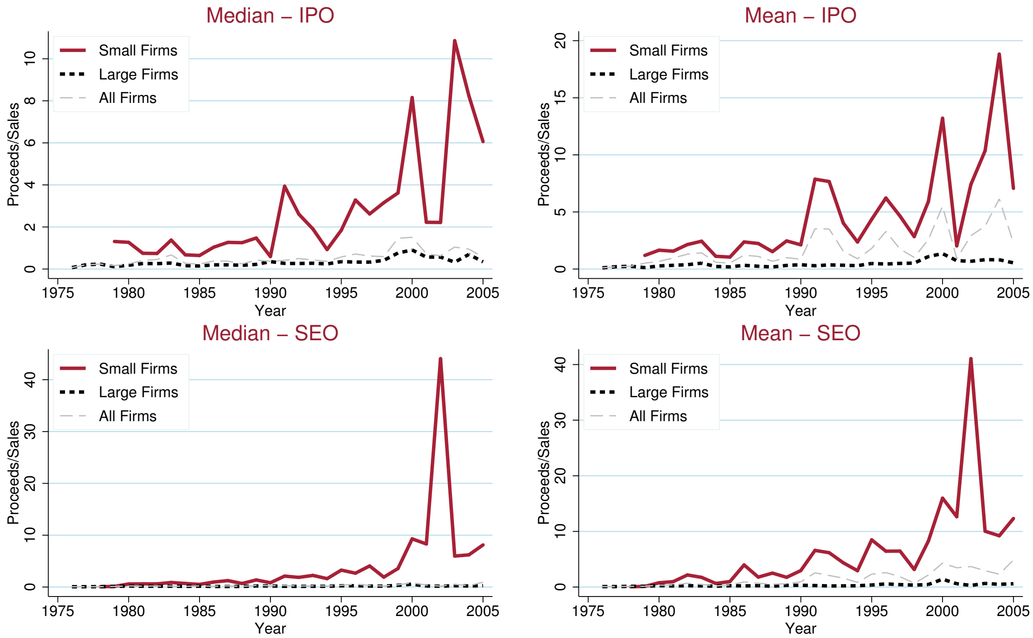


Figure A.8: Additional Equity Financing Facts. Sample includes all domestic manufacturing firms with annual (real) sales exceeding $1 mil and coverage in Compustat and SDC Global New Issues Database. Small firms are those with less than $25 million in (real) annual sales. Both panels plot the cross-sectional median and mean Equity Financing/Sales for small and large firms. The equity financing measure is defined as the proceeds from primary share issuance from IPOs (top panel) and SEOs (bottom panel) in the SDC database. Figure 2.3b plots the combined trends.