CIMR Research Working Paper Series

Working Paper No. 22

The Effect of Initial Public Offerings on Firm Innovation

by

Matthew Crail Johnson
+44 (0) 7903 172110
matt.crail.johnson@gmail.com

February 2015

ISSN 2052-062X

Abstract

The initial public offering (IPO) leads to significant growth in firm size as well as access to greater pools of capital available through the public markets, conceivably allowing public firms to devote ever-greater resources to pursuing innovation. This study seeks to discover how firm innovation is affected by an IPO, hypothesising that firms in fact become less innovative after going public due to increases in information asymmetries and potential for agency conflict between managers and investors. Managers are less inclined to pursue risky, uncertain, and long-term innovation projects in part because of the short-term, profit sensitive nature of unsophisticated and passive public equity investors. This is in contrast to the active role pre-IPO venture investors play in managing, controlling, and directing the firm, which lowers information asymmetries and potential for agency conflict. For this reason, these investors are better suited to distinguish between good and bad innovation projects, understanding the trade-offs between short-term profitability and long-term value building achieved through innovation. This study takes an empirical approach to testing the hypothesis, gathering data on patent grants (used as a proxy for innovation) for 202 US firms in the biotechnology, pharmaceutical, and medical supplies industries that went public between 1979 and 2002. The findings of the statistical analysis generally support the hypothesis, and suggest that the IPO acts as a brake on the growth trajectory of innovation in the years preceding and immediately following the IPO. Therefore, this study concludes that the IPO has *ex-post* negative effects on firm innovation.

Acknowledgements

This paper is a dissertation completed under the supervision of Professor Klaus Nielsen at Birkbeck, University of London in partial fulfilment for the requirement of MSc in Business Innovation. It is the recipient of the BIG prize for best dissertation in Innovation, 2013-14.

1. Introduction

The initial public offering (IPO) represents a major milestone for a firm. By facilitating liquidity it enables early investors to exit, rewarding them for the long-term and risky investment they made in an often young, innovative, and unproven firm. Among the several possible exit events, including acquisitions, leveraged buyouts, and liquidation, IPOs harbour the greatest upside in terms of potential return-on-investment (Cumming & Johan, 2008).

Early-stage equity investments, in part incentivised by an exit event, are critical in providing funding for the growth of new ventures. The earliest investments are generally made by the entrepreneurs themselves, as well as their friends, family, and business associates. After several years, the pool of potential investors expands to include angel investors and venture capitalists (VCs), who generally have the resources to provide greater capital to early-stage firms (Fluck, Holtz-Eakin, & Rosen, 1998). VCs, who in the US invest largely in high-tech, early stage companies (Black & Gibson, 1998), are a critical component of a vibrant innovation system. Despite VCs accounting for 3% of innovation investment in the US between 1983 and 1992, those investments generated 8% of innovative output, suggesting VCs are an efficient source of innovation financing (Kortum & Lerner, 2000). Most critically, VCs and their fellow early stage investors provide growth capital for young, innovative firms who would generally be unable to raise capital through traditional means, such as bank loans, because of the intangible, risky, and uncertain nature of innovation investments (Hall, 2010), coupled with the inherent risk in early-stage companies. Black & Gibson (1998) argue that a well-developed public stock market that provides an avenue for early-stage investor exit is necessary for a vibrant VC market, and thus for funding early stage innovation. Absent the potential for an IPO, the capital required by young firms to produce new knowledge, technologies, and innovations would be less prevalent. This suggests that IPOs have *ex ante* positive benefits on innovation.

The research question posed by this paper is what *ex post* impact does the IPO have on firm innovation? It seems logical that after going public firms should become more innovative because of enhanced capital resources. Firms on average triple in size (Carpenter & Petersen, 2002) through funds raised from the public issue, and this capital often does go to increasing investments in innovation, in the form of research and development (R&D) spending, in the years immediately following the IPO (Kim & Weisbach, 2008). Additionally, firms gain continued access to public markets where they can commence further equity issues, and in theory funding should always be available for net present value projects in perfect capital markets (Fluck et al., 1998). Therefore, firms that go public gain access to greater pools of resources internally and externally, which should conceivably contribute to improved innovative output.

This paper hypothesises that, in fact, firms become less innovative following an IPO despite access to greater resources. This is largely because capital markets are imperfect, especially in the context of the unique, idiosyncratic, and risky nature of R&D investments. These investments are characterised by the prevalence of information asymmetries and potential for agency conflicts between investors and managers. The IPO exacerbates these issues due to changes in ownership structure away from active private equity investors to passive public equity stockholders. The nature of R&D investment, characterised by a lack of tangible collateral as well as risk and uncertainty, raises the cost of capital and makes external capital and bank loans a prohibitively expensive and unlikely source for R&D investment financing (Hall, 2010). Beyond raising the cost of capital, information asymmetry and potential for agency conflict reduce a firm's ability to pursue innovation in a variety of ways. Public-equity investors generally have shorter time horizons, less access to information, and greater potential for divergent interests between themselves and management, inhibiting and even disincentivising management's discretion to conduct R&D (Bharath & Dittmar, 2010). Lack of information leads owners and potential investors to judge firms on relatively rudimentary and short-term metrics like quarterly earnings (Rappaport, 2005), pressuring managers to make decisions that increase short-term profitability at the expense of long-term investments. Further, managers become myopically fixated on increasing stock price, reinforcing a focus on short-term profitability rather than long-term value building (Stein, 1989). Passive investors who lack expertise in the technological basis of R&D investments are also poor judges of the long-term value of these projects, and find it difficult to distinguish between good and bad R&D projects (Hall, 2010).

Prior to going public, managers and investors experience relatively minimal information asymmetries and potential agency conflicts because of the nature of private equity investments, which are in general long-term, illiquid, and undertaken by investors with knowledge of the technology and industry in which the firm operates (Wright & Robbie, 1998). This confers positive benefits in terms of pursuing innovation as managers and investors can share a long-term approach to building firm value rather short-term profitability, including understanding of how R&D projects will positively or negatively contribute to building that value. Therefore, pre-IPO firms will have more freedom to pursue risky and uncertain, but potentially highly valuable R&D and innovation projects that are not as acceptable to investors of public firms, or even as appetising for managers in these public firms who are judged on earnings benchmarks and profitability.

This study takes an empirical approach to testing the hypothesis. Using patent grants as a proxy for innovation, 202 US firms in the biotechnology, pharmaceutical, and medical supplies industries are observed, beginning three years prior to the IPO through nine years after to determine how innovation output changed over time. The choice of industry focus is necessary to reduce potential internal validity issues due to the utilisation of patents, as these industries place greater emphasis on patenting as a method for appropriating value from innovation (Cohen, Nelson, & Walsh, 2000; Arundel, 2001). Measuring these industries limits the potential that a shift in patenting strategy is being measured, rather than changes in real innovation output.

The results of the empirical analysis indicate that preceding the IPO, through the first three to four years following it, innovative output grows rapidly. However, thereafter it begins to stagnate and decline slightly. This suggests, though not contributing to a sizable decline in innovation, the IPO functions as a braking mechanism on innovation growth, which does not keep pace with firm growth after going public. Therefore, based on the empirical research presented here, the IPO does appear to have a negative effect on the pursuit of innovation within firms.

This paper begins with a review of the literature to examine prior research that approaches a similar research question, as well as to develop the theoretical framework that informs the hypothesis. The literature review includes how information asymmetries and potential for agency conflicts impact the pursuit of innovation and R&D, how these issues are relatively minimised prior to the IPO, and how the post-IPO environment exacerbates them. The methodology chapter follows, outlining the expected outcomes of the statistical analysis, justification for the industry specific focus, and results of the regression models. This is followed by a discussion of the results, limitations, suggestions for future research, and a conclusion.

2. Literature Review

This study will discover whether firms in a pre-IPO, private equity environment are better suited for conducting R&D and producing innovative outputs than in a post-IPO, public equity environment. In the following section the nature of innovation and R&D investments will be discussed, as will prior literature conducted on this research question, followed by literature that informs the theoretical and empirical framework for the hypothesis presented by this paper. This will provide context as to where the empirical research conducted in this study fits into the broader literature surrounding ownership structure, investment, and innovation.

2.1. The Nature of Innovation and R&D

Innovation is primarily achieved through R&D investments, generally in the form of salaries for qualified researchers and engineers. Output from these investments is largely an intangible asset, namely knowledge, embedded in the human capital that created it. When this human capital exits the firm, the knowledge created through R&D investment exits with them. R&D is risky, uncertain, and costly, and when successful yields profits in the long-term, coming at the expense of short-term earnings. R&D outputs are commonly idiosyncratic and difficult to salvage value from if unsuccessful (Hall, 2010). This makes innovation investments unique to alternative forms of capital investments.

March (1991) identifies the explicit choice firms make between allocating scarce resources towards exploring new knowledge (i.e. innovating), and exploiting existing knowledge (i.e. leveraging prior knowledge/innovations). Exploration carries uncertainty and risk, and yields benefits in the long-term. Exploitation is relatively more certain and has capacity to generate profits in the short-term. Thus, pursuing exploitation too heavily and to the detriment of exploration confers short-term benefits, but is harmful in the long run and can lead to stagnation within the firm. How IPOs and subsequent changes in ownership structure affect the allocation of resources between pursuing exploration and exploitation form the basis of my research.

2.2. Public/Private Ownership and Innovation

Following the leveraged buyout (LBO) wave of the 1980's, Lerner, Sorensen, & Strömberg (2011) sought to measure to what extent the switch from public to private ownership form affects long-term investment, and R&D in particular. The debate they address, and which will be addressed in greater detail in coming sections, is whether or not the private organisational form relieves managers of public shareholder pressures that encourage short-term profit building at the expense of long-term value building, exemplified by investments in R&D. Their empirical research discovered that following the switch to a private corporate form patenting levels remained largely the same, and patent portfolios became more focused in areas where the firm previously specialised. They conclude that switching to the private form has no consequences on overall innovation-intensity, and generally cultivates a refocusing of innovation strategy on the firm's previous expertise.

Lerner et al., (2011) sheds light on the issue of innovation in a public versus private environment, but their findings are limited generally and in terms of applicability to the research objective of my paper in several key areas. First, strategic utilisation of patents as a method of innovation value appropriation varies by industry (Levin et al., 1988; Cohen et al., 2000). Lerner et al. (2011) lacks a focus on industries that place relatively greater importance on patents as a method for capturing value from innovation, thus their results do not account for potential shifts in patenting strategy when a firm is taken private. Second, while they do provide insight into the nature of private versus public ownership forms and how it effects on innovation, they looks at a shift in the opposite order to my empirical research. Third, their time frames (three years prior through two years following the LBO) are relatively short, and may not reflect the time it takes to renew innovative capacity. Finally, the innovative pre-IPO firms in my analysis are generally associated with different types of private equity investors than LBO firms, namely the entrepreneur and their friends and family, angel investors, and venture capitalists (Fluck et al., 1998; Prowse, 1998). VCs, for example, typically invest in new ventures, and generally do not take majority control. Private equity firms associated with LBO's, on the other hand, buy mature firms using a small amount of equity and a large amount of debt, and generally take majority control of the firm with a narrow focus on profitability (Lerner et al., 2011). Private equity in general confers positive benefits on innovative capacity, such as less information disclosure, as compared to public equity (Aggarwal & Hsu, 2014).

However, the structure of LBO’s, with high degrees of leverage and investments in mature firms, varies greatly from pre-IPO VC investments in fledgling, younger companies (Kaplan & Strömberg, 2008). Empirical research, for example, finds that greater degrees of leverage result in lower levels of innovation (Hall, 1990, 1994), which potentially limits positive benefits in terms of enhanced innovation output brought by the switch to a private ownership structure.

Ferreira, Manso, & Silva's (2012) model for private versus public ownership structure and firm incentive to invest in innovation suggests that private organisational forms are optimal when pursuing exploration because insider-investors can time the market and choose an early exit strategy when they receive bad news, making them more failure-tolerant and thus more inclined to invest in uncertain and risky R&D projects. Stock prices in public markets, on the other hand, accurately reflect all publicly available information. This makes an early exit once bad news is received unprofitable, which reduces risk-tolerance in public firms. Further, they suggest market prices react quickly to good news, incentivising short-term behaviour — meaning public firms are more conducive to pursuing exploitation and short-term profitability. The theoretical framework presented by me expands on this argument. The intention is to illustrate that pre-IPO private equity reduces information asymmetries and potential for agency conflict, leading to longer-term horizons and enhanced goal alignment between investors and managers. When uncertainties about quality and intended benefits of R&D projects are reduced, investors are less risk-adverse and more inclined to fund them.

Bernstein (2012), and Aggarwal & Hsu (2014) directly address the research question posed in this paper, comparing differences in patent citations (as a metric for innovation quality and level of novelty) between firms that conducted an IPO and firms that withdrew a planned IPO. Their findings support the hypothesis presented in this paper, indicating that firms who went public are less innovative than those which remained private. Once firms go public, they pursue less breakthrough innovations (exploration) and focus more specifically on incremental innovations (exploitation). Bernstein (2012) proposes an incentive shift as one underlying factor for this reduced innovative output, suggesting that inventors who experience ownership dilution, and thus have less of a claim on the monetary reward of their inventive outputs, face weaker incentives to pursue novel innovations, supported empirically by evidence that inventors who remain with the firm experience a decline in patent quality. Further, following the IPO there appears to be an exodus of inventors leaving the firm, though this is partially mitigated by the firm's ability to hire new inventors.

Aggarwal & Hsu (2014) take a similar approach to Bernstein (2012), with some distinctions. Their data sample includes exclusively venture-capital backed biotechnology firms, and they measure firms acquired through a merger and acquisition process (M&A) for comparison with firms that conducted an IPO. Their findings suggest a decline in patent applications for both IPO and M&A firms, the former's decline more pronounced. Further, firms acquired through an M&A by a private firm maintained relatively greater innovation quality than those acquired by public firms. Their results support their theoretical assertion that information disclosure is the root cause of innovation declines following an IPO or M&A. Private equity requires less public disclosure, therefore details of product or service innovations remain hidden from competitors, conferring greater competitive advantage in pursuing innovation. Conversely, public firms must make public disclosures, forfeiting the opportunity to be secretive and thus reducing their competitive advantage.

This paper is unique to prior research of Bernstein, (2012) and Aggarwal & Hsu, (2014) in several ways. First, a longer post-IPO data collection period will be measured in order to determine whether declines in innovation are temporary. Further, despite a similar industry focus as Aggarwal & Hsu (2014), my study expands beyond biotechnology into the pharmaceutical and medical supplies industries. Finally, my paper will base its conclusions on changes within firms that conducted an IPO, rather than between firms who completed and who withdrew their IPO. This controls for factors that potentially influence decisions to withdraw an IPO that could also influence innovation intensity.[1] For instance, market conditions and economic downturn inhibits innovation spending in the aggregate (Filippetti & Archibugi, 2011), as well as deters firms from conducting an IPO because of threat of undervaluation (Loughran & Ritter, 1995).

[1] Both studies consider changes within firms pre- and post-IPO. However, their conclusions stem from differences between completed and withdrawn IPOs. Regardless, their results can be compared to the empirical results found in this study.

Kim & Weisbach (2008) found that firms generally increased R&D spending following an IPO, suggesting that IPOs are motivated by a desire to finance capital investment. Further, Cohen & Klepper, (1996) found a positive correlation between firm size and R&D intensity. Conversely, Pagano, Panetta, & Zingales (1998) found that Italian firms decrease investment following an IPO, and the underlying motivation behind the IPO is to exploit overvaluation of similar firms in their industry. Further, much empirical research (Carpenter & Petersen, 2002; Hall, 2002, 2010) suggests that external equity financing is much too expensive for firms to utilise in financing R&D due to several factors which will be discussed in further detail shortly. As such, firms rarely make use of external debt or equity to fund innovation, suggesting that the IPO is an anomaly in externally financing R&D, and indeed Carpenter & Petersen (2002) point out that firms seldom conduct further equity issues following the IPO. Therefore, in the short-term an IPO likely enhances innovation because of increased resources that can be devoted to R&D. However, observing long-run patterns will potentially yield different results.

A further point is that Kim & Weisbach (2008) measured R&D inputs, rather than innovative outputs (Fang, Tian, & Tice, 2013). Thus, while IPOs lead to increases in R&D spending, other forces potentially hamper the effectiveness of this increased investment. This is perhaps due to inventor incentives, as proposed by Bernstein (2012), or negative effects on innovation due to information disclosure, as proposed by (Aggarwal & Hsu, 2014). In the following section, the role of information asymmetries and agency conflict will be discussed in reducing incentives to pursue or optimise R&D projects and innovation.

2.3. Ownership, Information Asymmetry and Agency Conflict

Following an IPO, firms on average treble in size (Carpenter & Petersen, 2002). This opens greater pools of capital to fund investment projects, and indeed under a neoclassical perfect capital market devoid of friction capital should always be available for positive net present value projects (Fluck et al., 1998). This suggests that the market should readily fund exploration projects that have positive returns on investment. Thus, because of greater liquidity and access to capital, a post-IPO firm would have greater resources available to conduct R&D. However, this perfect capital market model has been challenged in recent years (Carpenter & Petersen, 2002). Market friction does exist largely because of two factors: information asymmetries and potential for agency conflict (Carpenter & Petersen, 2002; Hall, 2002, 2010). These concepts form the theoretical basis for the hypothesis posed in this research paper.

Information asymmetries exist where the inventor/entrepreneur has better information than potential investors as to the nature and likelihood of success of potential R&D projects. Agency conflicts may arise where management is separate from ownership and there is potential for goal conflict, for instance where managerial freedom to pursue R&D projects is hampered by investor concern that the investment is self-serving rather than strategically valuable. Empirical evidence suggests these two issues raise the cost of capital for R&D as investors require larger premiums where information asymmetry and potential for agency conflict is high, limiting firms' ability to use external capital to finance R&D. Therefore, public equity is largely limited in its usefulness for innovation investments, with firms more reliant on internally generated funds for these types of investments (Carpenter & Petersen, 2002; Hall, 2002; 2010).

The hypothesis presented in this paper contends that reducing information asymmetries and agency conflicts not only reduces the cost of capital, but also encourages pursuit of innovation. This concept serves as the foundation for the remainder of the literature review, which will continue to build a theoretical and empirical framework for why firms become less innovative post-IPO. It will be established that *in toto* agency conflicts and information asymmetries are minimised pre-IPO relative to post-IPO. These concepts will be applied to existing theoretical and empirical literature in order to establish a relationship between them and organisational pursuit of innovation.

2.3.1. Pre- and Post-IPO Ownership Structures

Information asymmetries and agency issues differ between pre- and post-IPO firms due to the difference in the structure and makeup of investors/owners during the two periods. Pre-IPO, these issues are limited because private equity investors, particularly venture capitalists, take on an expanded role within the firm beyond simply supplying capital. Early in a firm's life equity investments tend to come from the entrepreneur themselves, as well as friends, family, and business associates. Later in their lifecycle (two to nine years) outside equity investors, specifically business angels and venture capitalists (VCs), become increasingly involved. Angel investors are generally high net worth individuals who invest their personal capital in young firms. They generally take a variety of hands-on roles within the firm in order to reduce information asymmetry and moral hazard as a means of risk reduction (Mason, 2007). VCs similarly invest in young, innovative firms, using funds raised through several large institutional investors. The VC acts as an intermediary between firm and investor, and takes an active role in funding, managing, and controlling the firm. They generally receive voting rights and seats on the board of directors, and even in some cases take on a managerial position. Prior to investing, VCs conduct intensive due diligence on the technology, market potential, characteristics of the management team, and financial fundamentals and potential profitability of the firm. Further, these investments are illiquid and long-term; often a VC fund has a lifetime of ten years and the VC anticipates an exit from the investment somewhere between two and seven years (Prowse, 1998; Wright & Robbie, 1998; Cumming & Johan, 2008; Schwienbacher, 2008). This active role taken by VC investors reduces information asymmetries in addition to acting as a governance mechanism, limiting potential for agency conflict (Wright & Robbie, 1998). In fact, Amit, Brander, & Zott (1998) argue that the VC's "niche" is specifically in dealing in areas where information asymmetry is potentially great, such as in innovative-intensive environments, due to their ability to limit information issues that can ultimately lead to moral hazard/agency conflicts. Thus, in a pre-IPO environment firms are characterised by investor stewardship, including greater degrees of owner-management, and reduced information asymmetries and agency conflicts, as well as a long-term orientation.

Following an IPO, liquidity increases and ownership becomes increasingly dispersed (Kothare, 1997), exacerbating information asymmetries and potential for agency conflict (Bhide, 1993). In contrast to a few active insider investors, ownership is spread throughout many passive, unsophisticated investors who find it costly to gather information on their investments (Bharath & Dittmar, 2010). This lack of information leads to increased reliance on short-term benchmarks such as quarterly-earnings in order to make decisions about investments, in contrast to hard analysis such as discounting cash flows (DCF) methods. Though analysts recognise that DCF is an appropriate model for evaluating financial assets, the cost and time of conducting such analysis, coupled with the fact that they will always have less information than insiders, inhibits their ability to produce accurate results, and contributes to the reliance on short-term benchmarks (Rappaport, 2005). Public equity investors tend to have limited oversight and control over firms they invest in, with little recourse to manage the firm other than through exiting the investment by selling their stock (Jensen, 1997).

2.3.2. The Influence of Investors on Management Decision-making

Graham, Harvey, & Rajgopal's (2005) survey of 401 financial executives discovered that a majority believed earnings were the key metric used by external audiences and investors to assess their firm, and indicated they would avoid beginning a positive net present value project if it came at the expense of the current quarter's expected earnings. Turning back to March (1991), this suggests that a firm's allocation of resources between long-term exploration projects and short-term exploitation of existing knowledge is influenced by investor pressures to meet short-term earnings benchmarks. Jensen (1997, pg.1) asserted that the "publicly held corporation… has outlived its usefulness in many sectors of the economy", in favour of the private form of corporate ownership. Because of substantial ownership by managers and directors, private firms seek to increase value over share price. Information asymmetries and agency issues are reduced in the private ownership form, and managers are insulated from share price being the key measure of firm performance. Stein's (1989) model suggests that manager concerns regarding share price influence them to behave myopically, forgoing long-term investments such as R&D in order to boost short-term earnings; the greater the concern about share price, the more myopically managers behave.

It is important to point out that Graham et al.'s (2005) survey included both public and private firms, and found similar results regarding short-term pressures between the two ownership structures. This certainly questions Stein's (1989) and Jensen's (1997) theoretical models, while also challenging an assumption in this paper's hypothesis that private, pre-IPO firms are insulated from these short-term pressures. However, several factors limit their finding's applicability to my research. First, just thirty-six private firms were included in their sample. Second, the type of private firm studied was not explicit. Many of the assumptions of my hypothesis centre not on the private equity ownership structure generally, but specifically on the pre-IPO ownership structure and its relative success in fostering innovation. The lack of focus on that specific type of firm, obviously not the intended purpose of their study, is limited in assessing the short versus long-term decision making of managers in the pre-IPO environment. Regardless, this study is useful in establishing a causal link that investors with short-term measurements of firm success impart short-term thinking on managers.

2.4. Effects on Innovation

Considerable literature exists examining the effects of information asymmetries and agency issues on general firm performance and, in some cases, specifically on innovation. Examining and synthesising this literature will establish the theoretical and empirical framework for my hypothesis and empirical strategy. Specifically, this section looks at how information asymmetry and agency conflict impacts innovation in firms. These two issues are manifested in a variety of ways, which will be discussed, and are often at the heart of previous empirical research that explores factors that effect innovation.

2.4.1. Liquidity

Firms conduct IPOs with the recognition that benefits of increased liquidity exceeds costs of decreased control (Bharath & Dittmar, 2010). Indeed, the driving force behind venture capital is a liquidity event, such as an IPO, that allows early investors to cash in on their long-term, previously illiquid investment (Zingales, 1995; Ritter & Welch, 2002). However, empirical evidence suggests that increased stock liquidity has a detrimental effect on innovation (Baker, Stein, & Wurgler, 2003; Fang, Tian, & Tice, 2013).

Illiquidity makes short-term exits difficult for investors (Wright & Robbie, 1998) whereas exits from public firms are often the sole governance mechanism an investor has at their disposal (Jensen, 1997). Illiquidity incentivises shareholders to be proactive in information gathering on firms they invest in. This reduces information asymmetries and potential for agency conflict between owners and managers, enhancing the investor's ability to distinguish between good and bad R&D projects. Due to their inability to sell in the short-term, investors by nature have a long-term focus which confers a long-term focus on managers (Lee & O'Neill, 2003). The argument presented here is that increased liquidity has an indirect effect on pursuit of innovation by decreasing incentives for investors to take active roles in information gathering. Instead, less informed and shorter-term metrics such as quarterly earnings are used to evaluate firm performance, as opposed to in-depth analysis of potential risks and benefits of R&D projects that reduce profit in the short term, but have the potential to increase firm value in the long-term. This is consistent with Fang et al.'s (2013) findings that dedicated institutional investors who actively gather information enhance innovative output, as opposed to investors who index holdings to short-term metrics that diminish innovation.

2.4.2. Stewardship

Kroll, Walters, & Le (2007) argue that, following an IPO, young firms would be better served by boards made up of insiders and top management members who share the tacit knowledge and entrepreneurial vision of the company and are thus better able to oversee the firm. Lee & O'Neill's (2003) cross-country research exploring differing R&D intensities between US and Japanese firms illustrates that owner-stewardship and reduced information asymmetry and agency conflict positively influence innovation. Japanese firms, in contrast to their US counterparts, are characterised by concentrated, relationship-based, and relatively illiquid ownership structures, and investors take a stewardship role in firms they own, including monitoring and controlling firm activities. Their study found greater R&D intensity in Japanese firms, and R&D intensity of US firms was positively correlated with ownership concentration.

Applying Lee & O'Neill's (2003) findings to US pre-IPO equity ownership structures, the logic would follow that relatively high levels of stewardship by these investors would increase R&D and innovative outputs of firms they invest in. While several studies have indicated that venture capital is associated with greater levels of innovation (Kortum & Lerner, 2000; Popov & Roosenboom, 2009), there is debate as to whether this is due to VCs picking already innovative firms, or whether stewardship actually improves innovative output (Hellmann & Puri, 2000). However, evidence suggests that a correlation exists between the level of firm monitoring and control exerted by VCs, and overall success of their portfolios, though not necessarily individual firms' propensity to innovate (Bottazzi, Da Rin, & Hellmann, 2008).

2.4.3. Manager Myopia

Faure-Grimaud & Gromb (2003) assert that public share prices incentivise managers to improve that price, as they are likely equity-holders as well. Share price reflects only publicly available information, so managers are encouraged to disclose information that might lead to an increase in share price. This has implications on innovation, as suggested by Aggarwal & Hsu (2014), in that increased information disclosure tempers innovation because the competitive advantage of R&D lies partially in secrecy. Thus, pursuit of increased share price through information disclosure is at odds with investments in R&D, and is reflective of the limitations in public markets to reduce information asymmetries in this regard due to the ease of imitation of inventive ideas (Hall, 2002).

Exacerbation of agency problems in public firms is manifested in management myopia. Career concerns encourage managers to be risk-adverse and focused on short-term earnings to bolster their reputation and decrease the likelihood of being fired for wasteful investments and missed earnings targets (Graham et al., 2005; Hall, 2002, 2010). Again, this myopia is largely driven by unsophisticated investors who rely on short-term profitability to assess firm strength (Rappaport, 2005) and are inclined to exit upon bad news (Jensen, 1997), and managers who focus on stock price become increasingly myopic at the expense of long-term value building (Stein, 1989). Pre-IPO, agency issues are reduced because of the active role investors play in managing the firm (Prowse, 1998; Wright & Robbie, 1998), which allows for greater goal alignment in pursuing long-term value building, a mutual understanding of the nature of innovation projects, and less reliance on short-term metrics to evaluate firm-investments.

2.4.4. Dividends and Free Cash Flows

Jensen (1997) argues that public investor pressure to pay dividends hamstrings a firm’s ability to make investments such as in R&D. Reduction of cash flows through dividends is employed by investors as a governance mechanism to reduce agency conflicts where managers potentially use cash flows to make self-serving investments such as luxurious offices or expanding beyond efficient scale (Hall, 2010). Indeed, private firms pay out less in dividends than do public firms, and the more dispersed the ownership of the firm, the more likely dividends are smoothed over time (Michaely & Roberts, 2011). Internal financing is most common for R&D

investments because of the expense of outside capital and limited availability of debt financing (Carpenter & Petersen, 2002; Hall, 2002, 2010), therefore reductions in cash available to management specifically interferes with investments in innovation.

Though public firms have access to greater pools of resources, rarely do they access external financing following the IPO (Carpenter & Petersen, 2002), and a greater share of internally-generated capital is paid out in the form of dividends. There is an argument to be made that overconfident managers will overinvest in innovation (Hall, 2010), therefore reducing cash available to managers through dividends prevents managers from spending on self-serving projects that create organisational inefficiencies (Jensen, 1986). Regardless, the pre-IPO environment should reduce this possibility because of the active oversight of the investor.

2.4.5. Investor Sophistication

Ferreira et al. (2012) suggest that private firms are able to take more risk and invest in R&D projects that are complex, difficult to describe, and untested, whereas public firms find it difficult to pursue projects that the market does not understand well. Again, Aggarwal & Hsu (2014) suggest that the very need to publicly disclose information to the markets will act as a brake on pursuing innovation itself. Thus, reduction of information asymmetry is limited in its effectiveness in providing freedom to pursue innovation for public firms (Hall, 2010).

The obvious benefits of keeping information about R&D secret in private firms is enhanced by the nature of the investors that early-stage firms disclose information to. Venture capitalists tend to focus their investments on specific industries, locations, or stages of the investment cycle (Prowse, 1998). Firms pursuing novel technologies require investors with expertise in their particular area of technology that can assess the quality of a firm's proposed innovation and make appropriate investments, which is the realm of venture capitalists (Tylecote & Conesa, 1999). This suggests that the value of information is relative to the capacity of the receiver to make sense of it. A VC with a technology or industry focus can make a better evaluation of the technology and its capacity to create future value than can a passive investor in the public equity market, where the lack of visibility of the R&D project can often be perceived as waste and inefficiency (Tylecote & Conesa, 1999), making VCs better judges of potential innovation projects. Further, unsophisticated investors with limited knowledge and thus highly asymmetric information must assign a higher premium to such projects because of uncertainty (Hall, 2010). Therefore, public equity investments in R&D suffer to a greater degree from Akerlof's (1970) "lemons" problem, where investors assign a higher price for uncertainty to compensate for inability to evaluate potential for success or failure. In other words, public equity investors have less ability to distinguish between good and bad R&D (lemons) and thus they are less receptive to R&D investments. On the other hand, venture capitalists are well suited for weeding out lemons through due diligence prior to the investment and their activity in managing and controlling the firm, in addition to their technological and market expertise in the area of their investments.

3. Methodology

The goal of the following empirical research is to explore whether, and to what degree, an IPO impacts the innovative output of firms. The hypothesis, that going public negatively affects innovative output, is informed by theoretical and empirical research suggesting that information asymmetries and potential for agency conflicts, exacerbated by the IPO, enhance short-term and myopic behaviour by managers, leading to a decline in the pursuit of innovation. This paper intends to discover whether this hypothesis is supported by patenting data, as a metric for innovative output, as well as explore the shape of changes in patenting output surrounding the IPO. The following section describes the hypothesis and expected outcomes, the approach taken to address the hypothesis, how internal validity issues are addressed, and the results of the statistical analysis.

3.1. Hypothesis

Firms will become less innovative following an initial public offering.

The hypothesis suggests that firms will experience a decline in innovative output following an IPO because of enhanced information asymmetry and potential for agency conflict between owners/investors, and firm management. It is theorised that prior to the IPO, firms should experience growth in overall innovativeness as they are plied with equity financing from sophisticated investors who take an active role in managing and monitoring the firm, allowing for greater innovative intensity because of investor stewardship (Lee & O'Neill, 2003). The decline in innovation should not occur immediately, however. Due to the immediate influx of capital from the IPO, which Kim & Weisbach (2008) suggests contributes to increased R&D spending, firms will likely see continued growth in patenting output. Further, pre-IPO insider directors tend to retain a bulk of their shares for some years following the IPO (Franks & Brennan, 1997), suggesting that dispersion and subsequent increases in liquidity are gradual, therefore the negative effects of enhanced information asymmetry and agency conflict on innovation will also be gradual. However, as these issues are enhanced by ownership dispersion, especially away from more sophisticated blockholders, institutional investors, and insider directors/owners, towards unsophisticated retail investors, coupled with the resulting liquidity increases that stem from dispersion (Zheng & Li, 2008), there would be an expected decline in innovative output a few years following the IPO.[2]

A further time lag issue arises because an investment in R&D does not immediately yield a patent, and thus changes in R&D spending may not be immediately reflected in patenting output. Hall, Griliches, & Hausman (1986) discovered that there is very little time lag between R&D investment and subsequent patent applications, meaning that increased investment in R&D should be reflected rather quickly in increased patent applications. However, their study observes firms in the US manufacturing sector in the 1970’s, and is thus potentially limited in its applicability to the firms being in my research. Darby & Zucker (2003) suggest that inventions are patented roughly three months following their discovery, however this provides little insight into when the investment that enabled that discovery was made. The firms being studied here likely have greater time lags relative to others due to the nature of clinical trials and the regulatory process in their industries, however research is lacking in quantifying what length those time lags might be.

Regardless, it is likely an unnecessary exercise to attempt to quantify a time lag between R&D investments and patenting because innovation is a nonlinear process. Linear models would suggest that a scientific discovery or a market demand leads to an idea to be researched, developed, manufactured, and then marketed. Instead, Kline (1985) suggests a chain-link model of innovation, where there are constant feedback loops throughout the innovation process. Thus, one investment might lead to several inventions/innovations at various times in the future. Further, modern innovation concepts include open innovation, where ideas and knowledge are leveraged from a variety of internal and external sources (Niosi, 1999; Chesbrough,

[2] Zheng & Li’s findings suggest that IPO underpricing is driven by the desire to increase liquidity following an IPO, though this is still achieved gradually.

2006). Therefore, it is difficult to determine what time lags might be observed between investments and patenting. In the context of a chain-link model, R&D investment now might be reflected in the shorter-term through a patent, but that investment might have longer-term positive impacts as well, where knowledge from that original discovery continues to yield new knowledge and subsequent patents for several years to come.

3.2. Approach

A positivist framework is used to approach the research question, leveraging empirical data to determine firm innovation in the years preceding and following an IPO. This is achieved using statistical analysis, and specifically regression curve estimation models. Aggregating collected data observations, a regression is applied to determine the overall innovative output of firms (the dependent variable), prior to and following the IPO (where time serves as the independent variables, specific to three years before IPO and nine years following the IPO).

Two regression curve estimation models, linear and cubic, are run in each test. Though hypothesised that a non-linear relationship exists, conducting linear curve estimations will reveal the overall patenting trajectory, allowing for an assessment of the hypothesis that patent output declines following an IPO. The cubic curve fit model will reveal a non-linear relationship if one exists, and allows for comparison with the linear relationship for model-fit. This method will both determine whether patenting output declines, as well as provide insight into the nature of patent output over time, allowing for the exploration of how long run patenting activity is affected by the IPO.

The two regression models will measure both the aggregated mean patenting counts on a per year basis of all the firms in the relevant data pool, as well as individual peryear patent counts. Mean patent data will provide an aggregated overview of the overall variations in patenting of the measured sample in order to infer the general shift of the group before and after the IPO. However, this presents an ecological fallacy that assumes the aggregated mean represents individual patent output. By also running individual observations in the regression models, this ecological fallacy can be avoided, and insight can be gleaned on an individual basis. A minimum threshold for statistical significance is set at 95%.[3]

3.3. Addressing Internal Validity

In order to operationalise the dependent variable, patent grants are employed as a metric for innovation. Acs, Anselin, & Varga (2002) found patents to be a reliable measure of innovation, and they are commonly used in empirical research (see: Cohen & Klepper, 1996; Kortum & Lerner, 2000; Popov & Roosenboom, 2009; Lerner, Sorensen, & Strömberg, 2011; Bernstein, 2012; Fang, Tian, & Tice, 2013; Aggarwal & Hsu, 2014).

The use of patents creates potential internal validity issues, where changes in patent counts following an IPO might less reflect a change in innovative output than a shift in strategy in appropriating value from firm-generated innovation. For example, empirical evidence suggests that firm value is positively correlated to increased patent numbers for both early investors such as VCs, as well as for the IPO valuation (Heeley, Matusik, & Jain, 2007; Hsu & Ziedonis, 2007). Therefore, pre-IPO firms perhaps face greater incentives to patent their inventions than post-IPO firms.[4] Conversely, the high costs of applying for and legally defending patents decreases the likelihood that small firms will use patents (Arundel, 2001) and large firms are more inclined to patent than smaller firms (Cohen et al., 2000) suggesting a bias in the opposite direction.

Indeed, not all innovations are patented. Arundel & Kabla (1998) found that on average 35.9% of product, and 24.8% of process innovations are patented. Firms utilise several strategies to appropriate value from inventions, in addition to patenting, including secrecy and lead-time. However, prior literature suggests that propensity to patent as an appropriation mechanism differs by industry, and suggests that medical supplies, pharmaceuticals, and biotechnology firms utilise patent to a greater degree than in other industries (Levin, Klevorick, Nelson, & Winter, 1988; Cohen et al., 2000). Limiting the study to these industries strengthens internal validity and enhances confidence that changes in innovative output, rather than changes in innovation appropriation strategy, are being measured.

---

[3] This statistical threshold is common in the social sciences.

[4] There is a difference between invention (creation of a novel idea) and innovation (practical or commercial use of an invention). Using patenting as a metric for innovation insinuates

3.4. Data and Descriptive Statistics

The Osiris database of listed companies was used to develop a comprehensive list of US firms in the biotechnology, pharmaceutical, and medical supplies industries that conducted an IPO between the years of 1979 and 2002. The measurement period ranges from 1976 until 2011, as data is observed for each firm starting 3 years prior to, and nine years following the IPO. Comprehensive patent data exists from 1976 until the present, necessitating the choice of beginning date.[5] The conclusion date of 2002 allows for the lag time between patent applications and patent grants, which takes an average of two years, and nearly all grants are approved within three years (Hall, Jaffe, & Trajtenberg, 2001).[6]

Two searches were conducted to target the intended industry-specific firms. The first search contained all firms with GICS[7] classification standards 352010 (biotechnology) and 352020 (pharmaceuticals). The second search included all firms with US SIC[8] codes 283 (drugs), and 384 (surgical, medical, and dental instruments and supplies). Two searches were necessary because of lack of consistency in industry classifications and the desire to include all biotechnology, pharmaceutical, and medical supplies firms. Roughly 10% of results from the Osiris database were unusable because of the lack of a clear IPO date.[9]

---

there is a commercial application for the patent, but a patent does not necessarily mean that the underlying intellectual property is an innovation until it is commercialised. However, in general patenting signals intent to innovate, therefore it is useful as a metric for innovation.

[5] The United States Patent and Trademark Office database contains patent data dating back to 1976, and was the original source used to collect data. However, all data was ultimately collected using the Google Patent Search, which actually includes patent data dating back to 1792.

[6] In the Hall et al. study, the last measured application years were 1990-1992. The authors found that 96.1% of granted patents were applied for in the preceding 3 years, and that throughout the years studied, lag time between applications and granting of the patent declined. While this potentially affects the patent counts in the tail end of measured years for firms that went public in the early 2000's, it will likely be slight.

[7] Global Industry Classification Standard.

[8] US Standard Industrial Classification.

[9] In many cases, firms were included in the list without a given IPO date. In others, a year was given, but no day or month. Subsequent web searches often yielded a date, however this was not always the case. Firms for which no IPO date could be found were dropped from the sample.

Patent counts were gathered from the Google Patent Database, which accesses all patent data from the United States Patent and Trademark Office. Searches were conducted using the firm name as the original assignee to be sure that is where the patent originated. Several factors were considered when conducting the search, including possibilities of different variations of the same company name, as well as changes to the company name. Online searches were conducted on the firm to see any mention of changes in the company's name. Further, patent searches on inventors tied to firm patents were conducted to discover potential past firm names and variations. Discrepancies were crosschecked via comprehensive online searches. Patent search results were thoroughly checked to ensure the proper firm was being measured. Firms with zero patents in the observed years were dropped from the sample. The date ranges of the search were patent application dates rather than patent grant dates to more closely reflect the time at which the investment and subsequent invention occurred due to the considerable lag between application and grant in many cases (Hall et al., 1986). This study only considers patents that were granted, rather than all patents applied for by firms.

Figure 1 – Sample Breakdown by Industry

GICS Code	Industry	Frequency	Percent
30302010	Personal Products[10]	3	1.5
35101010	Healthcare Equipment	57	28.2
35101020	Healthcare Supplies	24	11.9
35102015	Healthcare Services	1	.5
35103010	Health Care Technology	3	1.5
35201010	Biotechnology	80	39.6
35202010	Pharmaceuticals	28	13.9
35203010	Life Sciences & Tools	6	3.0
Total		**202**	**100.0**

Ultimately, an N of 202 firms is available to test the hypothesis. The breakdown of firm types can be seen in Table 1. GICS codes are used to classify the firms by industry for consistency.

3.5. Results

The aggregate mean and individual models are run on four different samples of the dataset. The first set contains patent figures for all 202 firms in order to discover the overall patenting trends before and after the IPO. The second subset is referred to as "intensive innovators", and includes the most innovative overall firms in the dataset. The third subset contains firms that were relatively innovative prior to the

[10] Personal products industry includes firms who produce toiletries, personal hygienic, and birth control products.

IPO, called “first-half innovators”. The fourth subset includes firms that remained innovative following the IPO, called “second-half innovators”. The justification for differentiating between these various subsets will be discussed.

3.5.1. Total Sample Models

The following models contain aggregate mean and individual data from the total sample of 202 firms. From this, the overall patent intensity is shown over time. As shown in Figure 2, the linear equation has a p value of .005 allowing for rejection of the null hypothesis, thus yielding a statistically significant variation in patenting over the observed period of 3 years prior to through nine years following the IPO. The r square suggests this model accounts for 50.4% of variation in the observed data. The cubic equation yields a p value of .001, again allowing for rejection of the null hypothesis, meaning a statistically significant variance in patenting over the observed period exists. The r square figure suggests that this cubic regression model accounts for 85.9% of variance in patenting.

Figure 2 - Total Sample Mean Patent Output: Model Summary

Dependent Variable: Patents_mean_1

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.504	10.152	1	10	.010	1.949	.127		
Cubic	.859	16.312	3	8	.001	.486	.907	-.097	.003

The independent variable is Year.

Figure 3 - Total Sample Mean Patent Output[11]

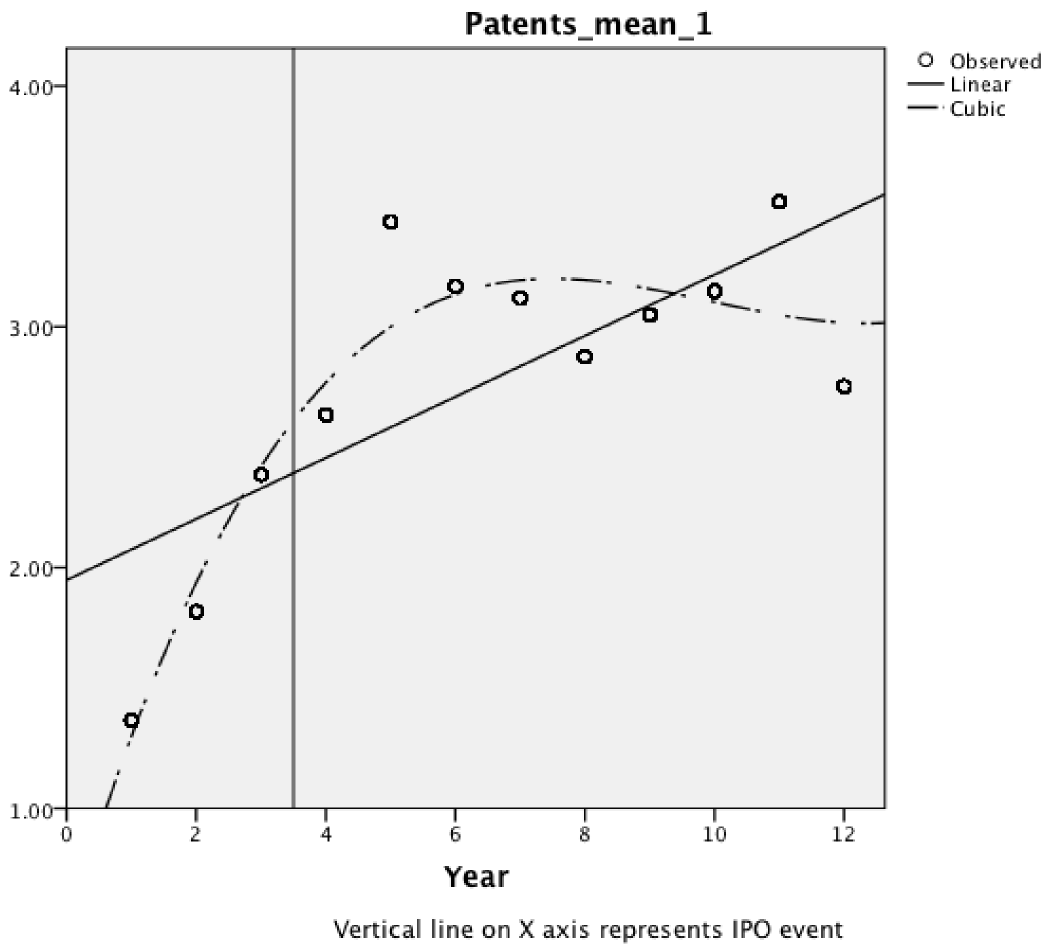


Figure 3 maps the regression equations. The linear model conflicts with the hypothesis, showing an increase in patenting over time. Conversely, the cubic equation curve shows rapid growth in patenting in the three years preceding the IPO through two years following, when growth slows. In the fourth year following the IPO, patent numbers begin a subtle decline before levelling off nine years following. The cubic model, which is more robust than the linear model, therefore lends support to the hypothesis.

The next models measure all observed patent figures per year for each firm in the sample, rather than the entire samples per year mean patent figures. As shown in Figure 4, both the linear and cubic equations are statistically significant, allowing for rejection of the null hypothesis. The linear equation's r square suggests this model accounts for 0.7% of variance in observed data. The cubic equation's r square is similarly low, accounting for 1.2% of variance in observed data.

[11] In SPSS, years were recorded as positive figures. In the charts year 1 corresponds with 3 years prior to the IPO, and year 12 corresponds with 9 years following the IPO.

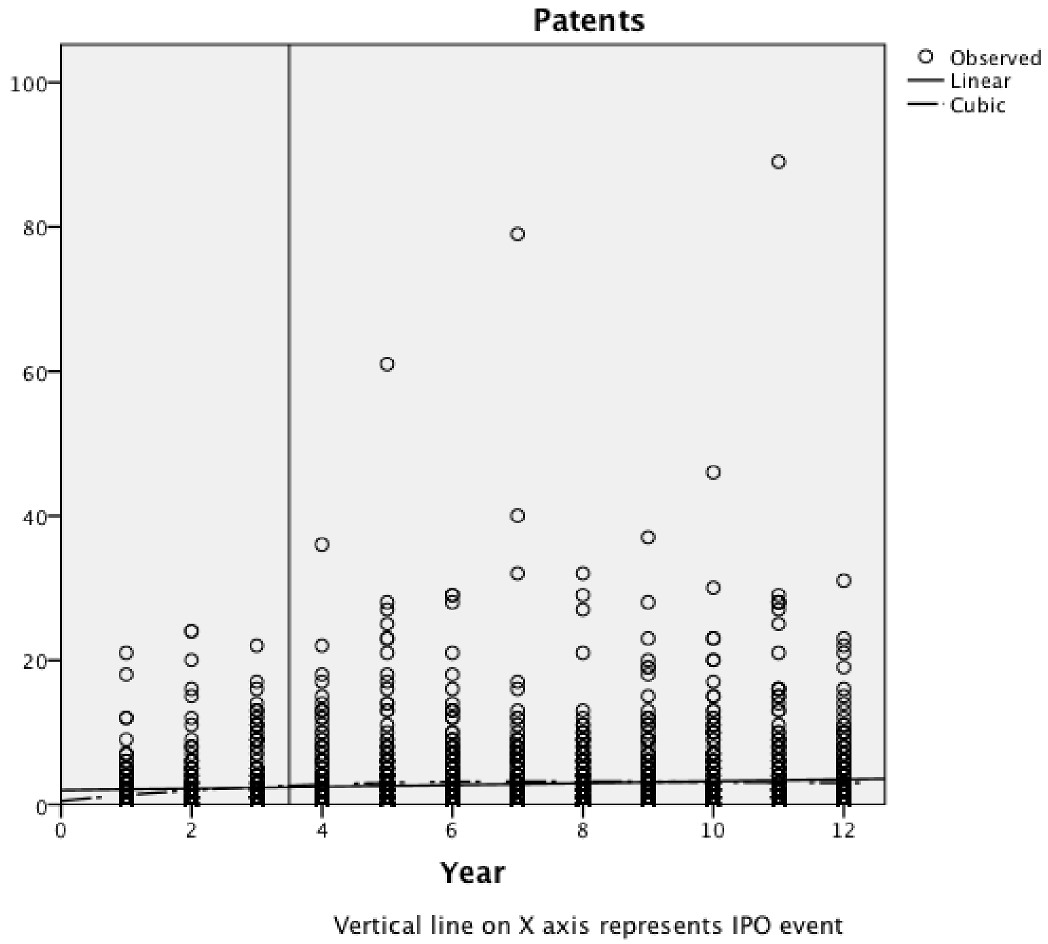
Figure 4 - Total Sample Individual Patent Output: Model Summary

Dependent Variable: Patents

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.007	16.487	1	2422	.000	1.949	.127		
Cubic	.012	9.413	3	2420	.000	.486	.907	-.097	.003

The independent variable is Year.

Figure 5 - Total Sample Individual Patent Output



The regression models in Figure 5, which take into account individual patent observations, yield little information. The linear model reflects a slight increase in patenting activity over time, again conflicting with the hypothesis. The cubic equation, on the other hand shows a slight increase in patent output until four years following the IPO, before a gradual decline begins. Despite being statistically significant, these models are quite weak.

A factor contributing to the weakness of these models is the variance in patenting outputs among firms. For instance, in year eight following the IPO, one firm produced nearly 90 patents. However, most observations fall below 20 patents per year, and in many cases firms recorded zero patents for a given year. This floor for observations produces a weak model, especially when compared to the quite robust mean patenting models. Attempts to rectify this measurement issue were problematic. The only approach that improved the individual measurement models had mixed results, and is done by measuring patent counts per year as a percentage of the firms patent output in the overall observed period. The models conducted on subsets of the data sample all showed improvements to the model fit by using this method, though the overall sample model worsened. Therefore, in the following sections, the individual observation models utilise patents per year as a percentage of the firm's overall patent output in the measured years, referred to patents as percentage of total.[12]

3.5.2. Intensive Innovators

Intensive innovators include firms in roughly the top 50th percentile of overall patenting activity throughout the twelve observed years, translating to all firms with twenty plus total patents. This allows for analysis of firms with relatively greater innovative capacity or focus, which serves two purposes. First, it rids the data of many of the zero observations to try and reveal a more robust individual patent observation regression model. Second, it allows for observation of firms that are relatively inclined to innovate to discover if they are more affected by the IPO. As shown in Figure 6, the linear equation shows statistical significance indicated by the p value of .005, allowing for rejection of the null hypothesis. The r square suggests this model accounts for 57% of variation in the observed data. The cubic equation is also significant, with a p value of .001. The r squared indicates that 85.4% of variance is accounted for in this model.

Figure 6 - Intensive Innovators Mean Patent Output: Model Summary

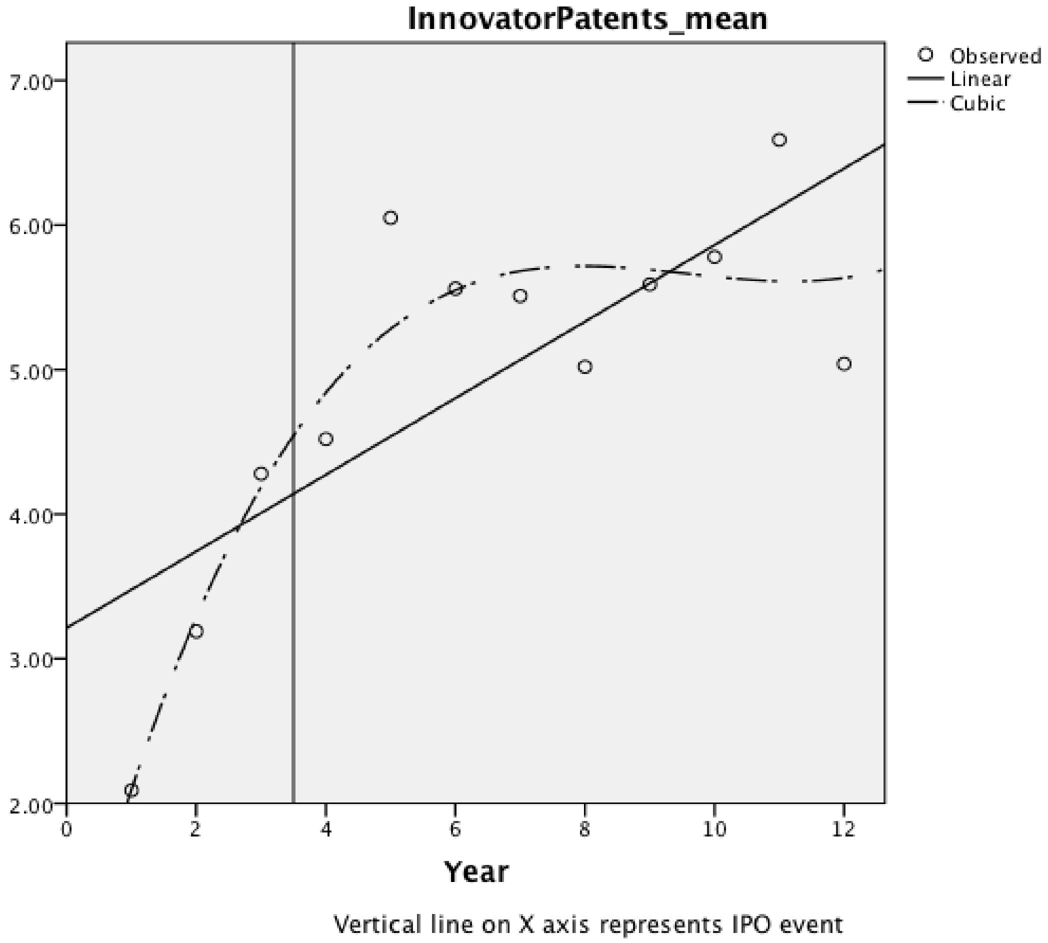
Dependent Variable: InnovatorPatents_mean

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.570	13.254	1	10	.005	3.213	.265		
Cubic	.854	15.647	3	8	.001	.580	1.690	-.182	.006

The independent variable is Year.

[12] For example, if a firm had 100 patents in the 12 years of measurements this study takes into account, then their year one observed patent total of 15 would yield a measure of 0.15, year two observation of 8 patents would yield a measure of 0.08, etc.

Figure 7 - Intensive Innovators Mean Patent Output



The regression curves in Figure 7 are similar to that of the overall sample. The linear equation suggests an overall growth in patent activity for the relatively innovationintensive firms, detracting from the hypothesis. However, the cubic equation, a better-fit model, reveals pre-IPO rapid growth in innovation intensity that levels off four years after the IPO, followed by a slight decline, and finally an uptick nine years after going public.

Turning attention to individual yearly patents as percentage of total models yields statistical significance for both the linear and cubic equations, with p values of .000, shown in Figure 8. The linear equation's r square suggests this model accounts for 3.3% of variance, while the cubic model is slightly greater at 5.8% of variance. Though significant, the individual models again yield weak results.

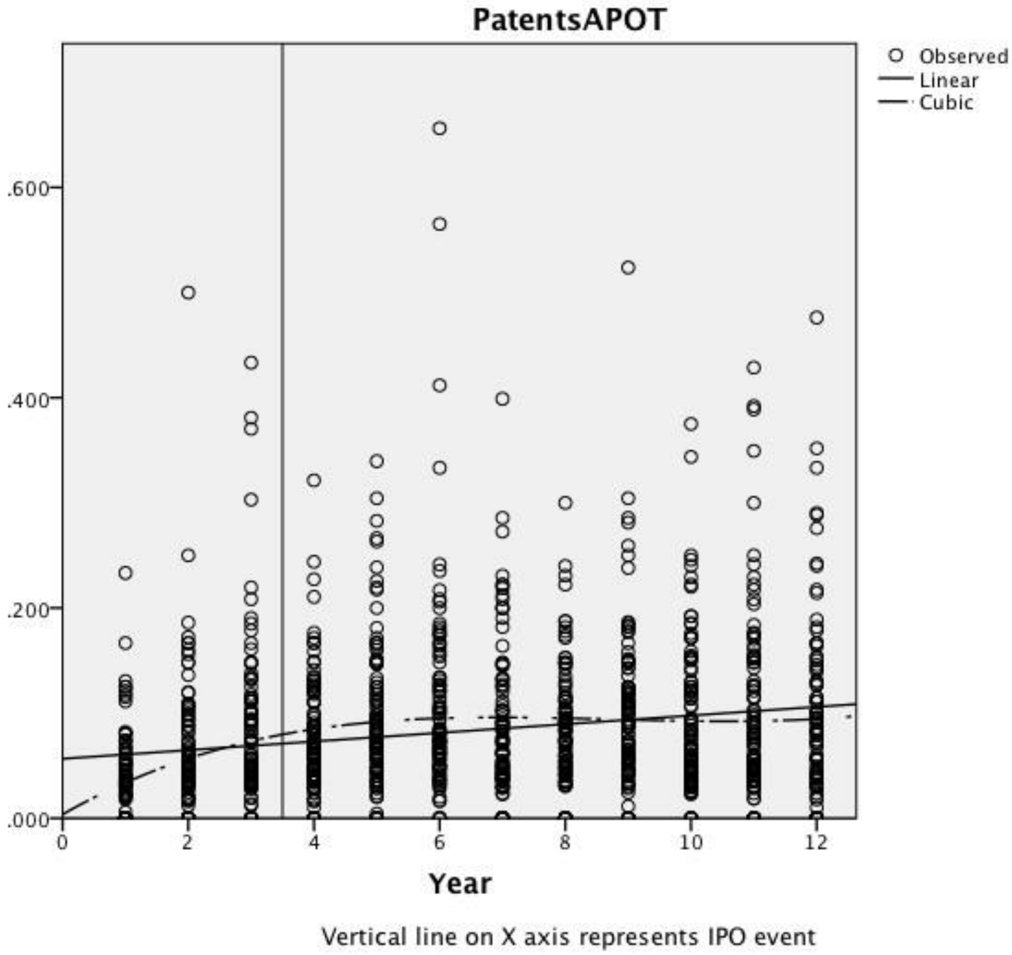
Figure 8 - Intensive Innovators Individual Patent as Percentage of Total Output: Model Summary

Dependent Variable: PatentsAPOT

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.033	41.486	1	1198	.000	.057	.004		
Cubic	.058	24.328	3	1196	.000	.004	.034	-.004	.000

The independent variable is Year.

Figure 9 - Intensive Innovators Individual Patent as Percentage of Total Output



Observing the regression curves in Figure 9, the linear model again suggests an overall rise in the number of patents over time, while the cubic model suggests that growth in patent output peaks three years following the IPO, before a gradual decline, again with a slight uptick nine years after the IPO.

3.5.3. First Half Innovator Models

This subset contains firms classified as “first half innovators” classified as firms in the top 50th percentile of total patenting output in the first six years of collected data. In other words, these firms were relatively innovative in the years preceding and immediately following the IPO. This allows for analysis of whether relatively innovative firms prior to an IPO are more or less affected by the IPO.

Results in Figure 10 shows that the linear equation for this subset is below the minimum statistical significance threshold, and thus the null hypothesis cannot be rejected. While it would indicate an overall growth in patent intensity over time, the r square also indicates that it accounts for only 32.3% of variance in the model, and is regardless dropped from analysis. The cubic equation however meets the statistical significance threshold, with a p value of .005, and the r square indicates this model accounts for 78.2% of variance.

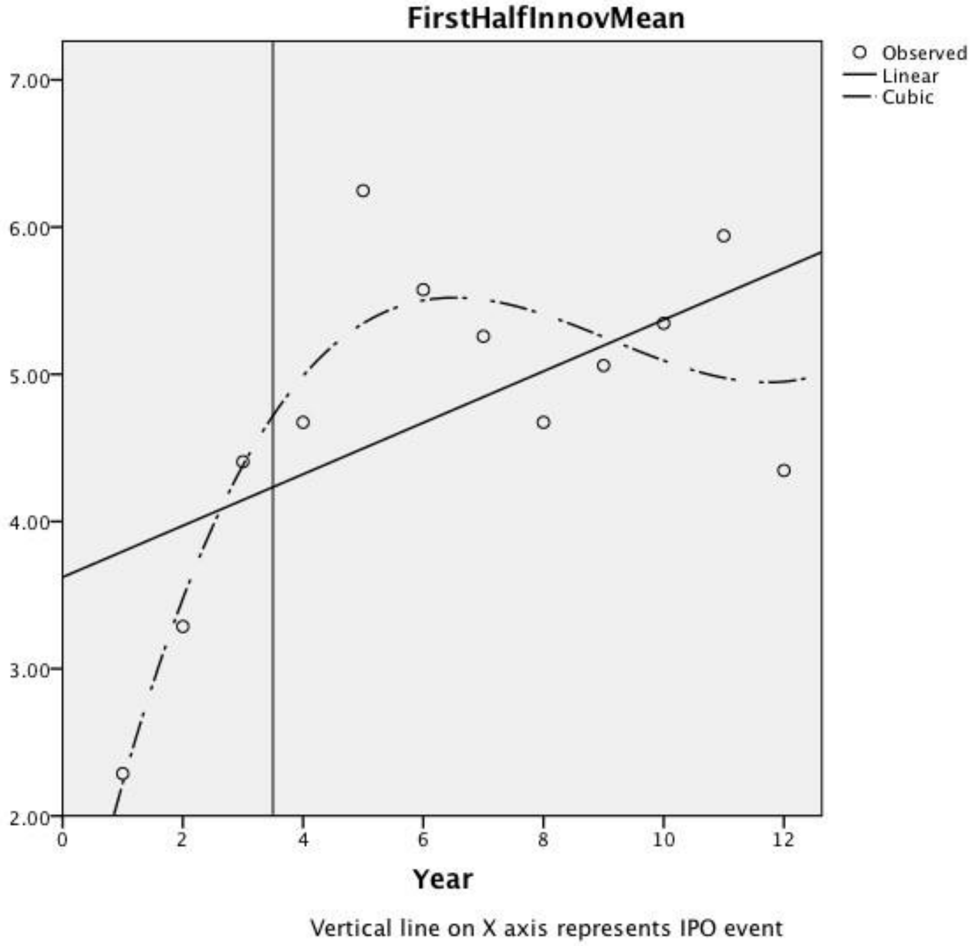
Figure 10 - First-Half Innovators Mean Patent Output: Model Summary

Dependent Variable: FirstHalfInnovMean

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.323	4.766	1	10	.054	3.622	.175		
Cubic	.782	9.557	3	8	.005	.574	1.863	-.222	.008

The independent variable is Year.

Figure 11 - First-Half Innovators Mean Patent Output



The cubic model reveals a steady growth in patent grants until three years following the IPO, followed by a noticeable decline in patenting through nine years after, more so than models from other data subsets. Obviously a selection bias issue exists because these firms were picked specifically for their innovative intensity prior to the IPO, and thus comparisons against the other data subsets is problematic. What it does show is that innovation-intensive firms prior to going public see rapid expansion of their innovation output, only to experience a decline three years after going public.

Figure 12 - First-Half Innovator Individual Patent as Percentage of Total Output: Model Summary

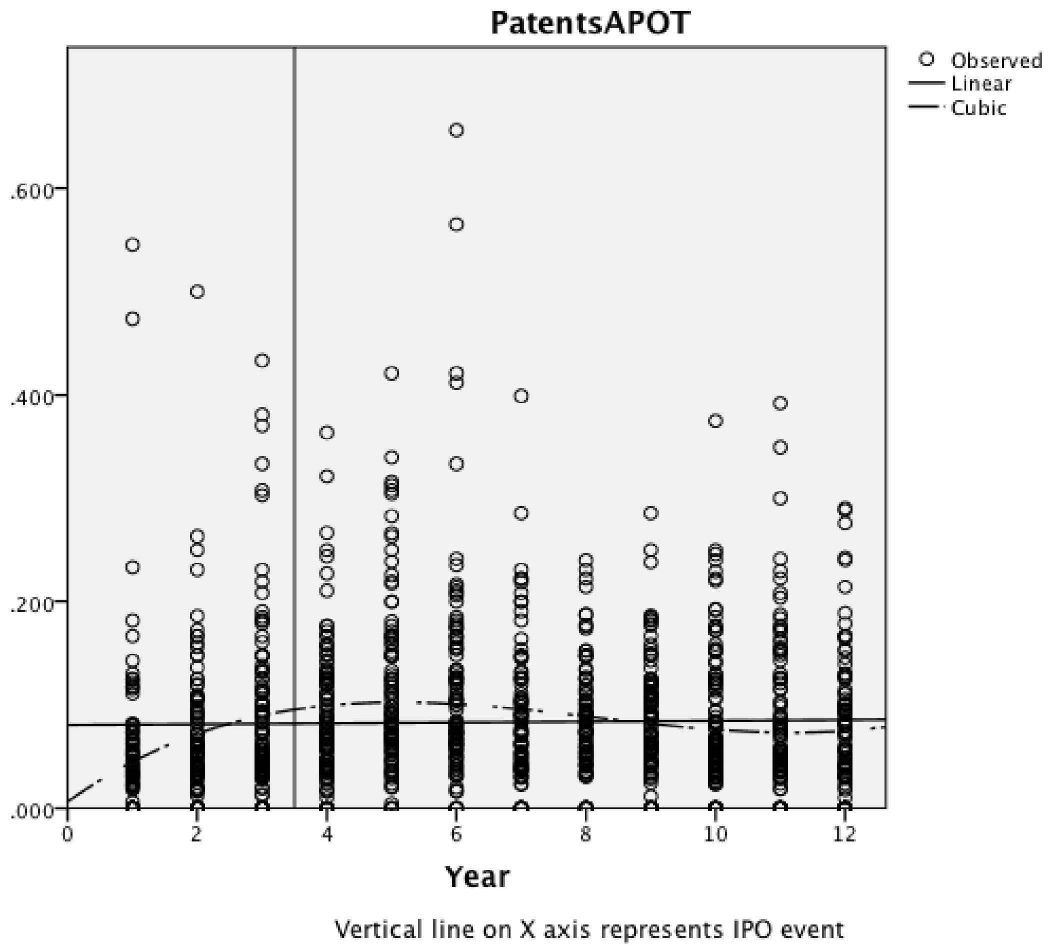
Dependent Variable: PatentsAPOT

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3

Linear	.000	.369	1	1210	.544	.081	.000		
Cubic	.040	16.963	3	1208	.000	.006	.044	-.006	.000

The independent variable is Year.

Figure 13 - First-Half Innovators Individual Patent as Percentage of Total Output



The individual models again use yearly patents as a percentage of the firm's total to quantify changes in patenting output. Figure 12 displays a linear model with a p value of .544, suggesting there is no statistically significant linear change in overall patent output of first-half innovators, and this model is dropped from the analysis. The cubic equation on the other hand has a p value of .000, and is thus statistically significant. The r square is again low for the individual model, capturing only 4% of variance. However, the individual trend is certainly similar to the mean patenting trend, with firms improving their innovative output pre-IPO, and the actual decline beginning a slightly earlier at two years following the IPO before levelling off and slightly increasing in the eighth and ninth years following the IPO.

3.5.4. Second Half Innovator Models

This subset contains firms classified as "second half innovators" and is comprised of firms in the top 50th percentile of total patenting output in the last six years of observed data. This will determine whether or not firms that were relatively innovative following the IPO were also comparatively innovative previously. Roughly 40% of firms fall into both first-half and second-half innovator categories, and 78% of firms that were relatively innovative prior to the IPO remained innovative following it. The linear and cubic equations, shown in Figure 14, are statistically significant, with a p value of .001 and .000 respectively. The linear equation's r square suggests this model accounts for 67.9% of variance, while the cubic equation accounts for 89.1% of variance.

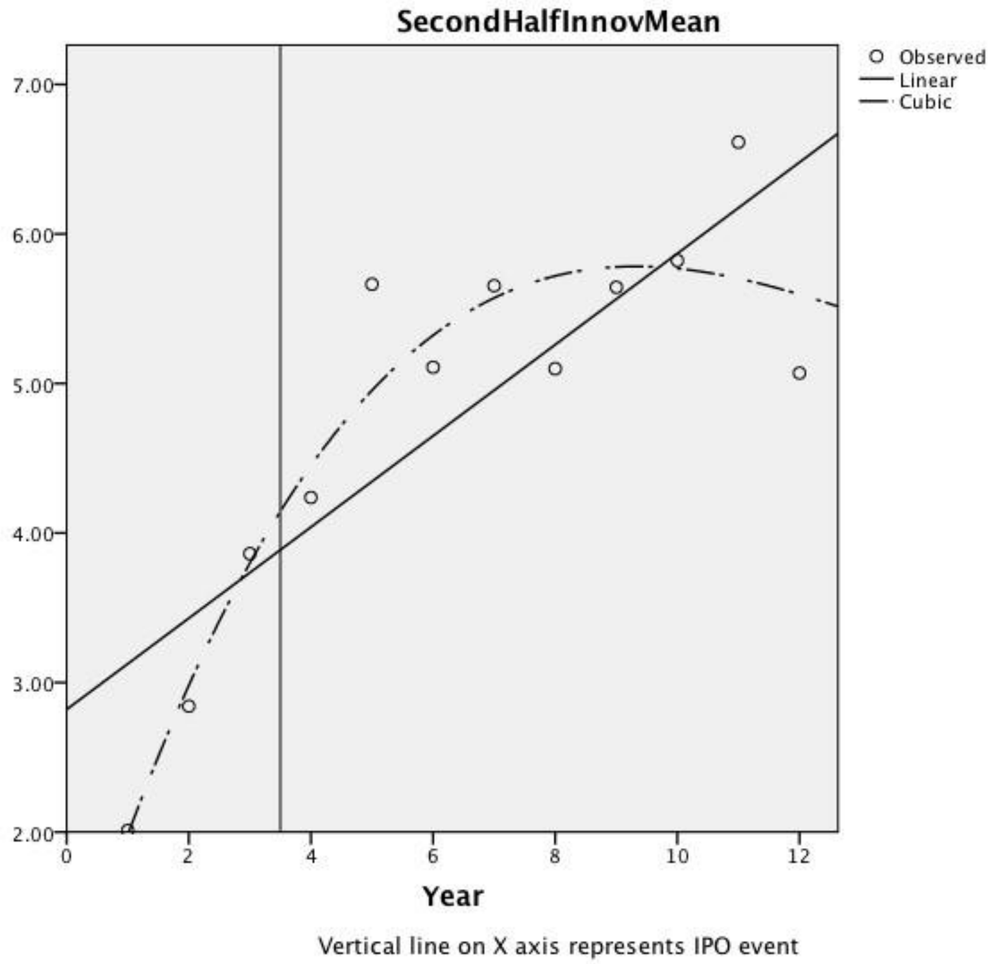
Figure 14 - Second-Half Innovators Mean Patent Output: Model Summary

Dependent Variable: SecondHalfInnovMean

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.679	21.110	1	10	.001	2.820	.305		
Cubic	.891	21.750	3	8	.000	.785	1.300	-.106	.003

The independent variable is Year.

Figure 15 - Second-Half Innovators Mean Patent Output



Once again, selection bias of firms with relatively greater patent output in the latter years of the observation period limits the effectiveness of comparison with other models. However, on its own some details can be gleaned regarding firms that remain relatively innovative in the post-IPO period. As shown in Figure 15, the linear equation indicates a sharp overall increase in patent output over the observed period. The stronger cubic model, however, shows a broadly similar patent trajectory as the other models. There is a rapid growth in patent output, which slows down four years after the IPO. Between six and seven years following the IPO, this patent output begins a gradual decline through the end of the observation period. This suggests that even the firms that remain relatively innovative following the IPO do see an eventual decline in patent intensity.

The individual yearly patent as percentage of total models yields significant results for both the linear and cubic equations, with p values of .000, shown in Figure 16. The linear model’s r square suggests it accounts for 8.2% of variation, while the cubic equation is slightly stronger, accounting for 10% of variation. Like other individual models, these results are quite weak.

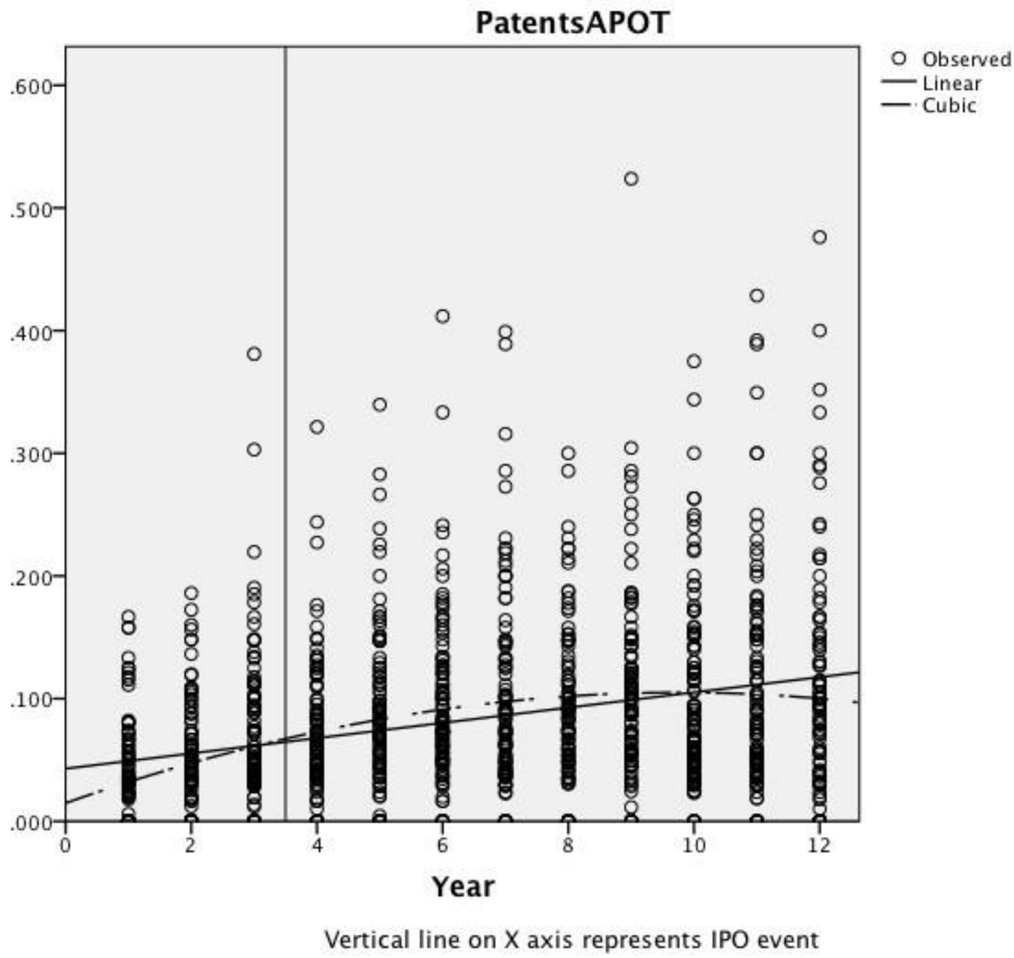
Figure 16 - Second-Half Innovator Individual Patent as Percentage of Total Output: Model Summary

Dependent Variable: PatentsAPOT

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.082	108.055	1	1210	.000	.043	.006		
Cubic	.100	44.558	3	1208	.000	.015	.018	-.001	-4.379E-006

The independent variable is Year.

Figure 17 - Second-Half Innovators Individual Patent as Percentage of Total Output



The models, shown in Figure 17, do closely resemble the mean patent models. There is an overall increase in patenting activity as suggested by the linear model. The cubic model shows growth in patent output peaking five years following the IPO, followed by steady decline through the rest of the observation period. Compared to other models, this decline in patenting occurs rather late, but occurs nonetheless.

4. Discussion

With empirical results in hand, this section presents an analysis of the regression models in the context of existing literature, followed by limitations and suggestions for further research in this field.

4.1. Results Analysis

The evidence gathered generally supports the hypothesis presented by this paper, indicating that the IPO negatively impacts innovation output in firms. While the linear regression models indicate an overall increase in patents over time, the more robust cubic regression models show small declines in the years following the IPO. The cubic curves of the various subsets of data analysed consistently show a rapid increase in patent output in the pre-IPO years, after which growth tends to slow before flattening out or declining in the three to four years following the IPO, even with firms that were relatively innovative in the last six years of observation. Because these declines in patent counts are slight, it is perhaps more accurate to say that the IPO acts as a brake on the rapid growth of innovation that occurs prior to going public, rather than resulting in large-scale declines. This stagnation and decline is especially pronounced when the growth in firm size following an IPO is considered (Carpenter & Petersen, 2002). Despite growing the pie in terms of resources available to fund innovation, a decreasing share of that pie is being devoted to innovation following after going public.

These results can be compared with empirical results from studies with a similar research focus. Bernstein (2012) found that patent quality, measured by patent citations, began to decline two years following the IPO, which is earlier than the observed decline in patent totals in my study. Interestingly, he found no change in patent applications in the years around the IPO event, in contrast to the results presented here. This discrepancy potentially lies in his use of applications as opposed to granted patents, in addition to the lack of industry focus and differing statistical methods. Aggarwal & Hsu (2014), with a similar industry focus as my study, found a 36% decline in patent applications in the three years following the IPO. This conflicts with my findings that growth in patenting continues through the first four years following the IPO, before slightly declining. Again, the use of applications versus grants, variations in statistical analysis, as well as my slight expansion of industry focus and pre-IPO investor types potentially explains some of the divergence.[13] Regardless, my overall findings generally support those of Bernstein (2012) and Aggarwal & Hsu (2014), adding further evidence that IPOs negatively impact innovation.

Sørensen & Stuart's (2000) study of the relationship between firm age and patent output found an inverted U shape relationship for biotechnology firms. The first ten years of a biotech firm’s life generates increased patenting before an observed decline. Firms generally go public within ten years of incorporation (Garfinkel, 1993;

[13] Aggarwal & Hsu’s (2014) study included only venture capital backed biotechnology firms.

Corwin & Harris, 2001), therefore my results are similar to that of Sørensen & Stuart, (2000), where through the first two years following the IPO (year ten on average of a firm's life), patent output increases, and their study likely in part reflects a decline due to an IPO event. However, there are only slight declines in my empirical evidence, potentially because of their longer observation period.

Perhaps most surprising from the empirical results is the continued rapid expansion of patent grants in the years preceding and immediately following the IPO. This reflects a pre-IPO commitment to innovation that does not continue for long after going public. As the firm grows approaching this event, innovation grows as well. However, once going public this innovation growth declines. Kim & Weisbach (2008) found that capital raised from an IPO is allocated over a period of years, and in the four years following an IPO this capital is used to increase R&D spending. They conclude that one of the primary drivers of the IPO is a desire to fund R&D and capital expenditure projects. This is remarkably consistent with the empirical findings of this paper, where patent output declines four years following the IPO in the total sample of mean patenting data. However, R&D investment growth does not appear to last, or becomes less effective in producing patents. This is consistent with findings that firms tend to smooth R&D over time (Hall et al., 1986) in an effort to avoid laying off the human capital in which the fruits of R&D expenditures, namely knowledge, resides (Hall, 2010). Thus, the IPO's positive effect on R&D and innovation appears to be temporary. This fact also lends support to Bernstein (2012)**,** who argued that innovation quality likely declines because inventors have less economic stake in successful R&D outcomes after the IPO, and are therefore less incentivised to create novel inventions. This is a symptom of agency conflict, where reduced ownership leads to suboptimal outputs in terms of firm innovation.

The post-IPO lag preceding the observed decline in patenting is expected due to the nature of the IPO. Increased information asymmetries and agency conflicts due to dispersed ownership and increased liquidity are gradual rather than sudden. This is because, in general, insider investors as well as blockholders and institutional investors who can efficiently gather information and thus reduce information asymmetries and potential for agency conflict, remain owners of the firm in the near-term. This is for several reasons: 180 day post-IPO lockup periods prohibit pre-IPO owners from sale of stock in that period (Field & Hanka, 2001), insider directors tend to retain a bulk of their shares for several years following the IPO (Franks &

Brennan, 1997), and blockholders tend to sell as the stock becomes more liquid in order to prevent dilution of the share price (Helwege, Pirinsky, & Stulz, 2007). In fact, firms tend to underprice their IPO's partially to encourage liquidity and dispersed ownership (Pham, Kalev, & Steen, 2003; Ellul & Pagano, 2006; Zheng & Li, 2008). This decline in insider ownership and block holding is gradual, but within five years of the IPO insider-owners on average own less than 10% of outstanding shares. Therefore, the gradual exacerbation of information asymmetries and agency conflicts eventually negatively impacts innovation. Despite a tripling in size (Carpenter & Petersen, 2002), and initial post-IPO capital expenditures on R&D (Kim & Weisbach, 2008), the eventual wedge between management and investors begins to slow down and ultimately lead to slight declines in innovative output of newly public firms.

4.2. Limitations

The most compelling models in this empirical study took into account mean patenting data for all firms measured in the given sample. However, when individual patent numbers were run in the regression models, though generally statistically significant, the results were less robust. Thus, while conclusions can be drawn that for the overall samples patenting stagnates and slightly declines following an IPO, less compelling evidence exists on an individual-firm observation level. This is partially due to the many zero-observations for patent grants in a given year in the dataset.

A further limitation stems from the effect firm growth has in creating an organisational structure less suited for innovation. As firms age and grow larger, they become less reliant on fungible resources which foster innovation, and increasingly reliant on rigid rules, processes, and values that compromise and discourage pursuit of innovation (Holmström, 1989; Christensen & Overdorf, 2000). When firms conduct an IPO they, on average, experience a three-fold increase in size (Carpenter & Petersen, 2002), thus they are likely to experience pressures to adopt a more bureaucratic structure following an IPO to accommodate greater scale. This raises the threat that what is being measured does not reflect increased pressure to maximise short-term profitability at the expense of long-term exploration and innovation, but instead the natural consequence of the necessity of many firms to rely on rigidity, processes, and values as they grow to manage an ever larger organisation.

Further, as firms age they perhaps make a rational choice to not pursue innovation. According to March, (1991), firms must choose to allocate resources between exploration and exploitation. However, in order to exploit knowledge, firms must first produce knowledge. Therefore, patenting potentially declines as firms age because of a rational choice made by management to reap the benefits of prior investments and risk, rather than reflecting a suboptimal outcome influenced by managerial myopia and short-term investor metrics. This is perhaps part of a natural firm life cycle to devote resources towards exploitation to the detriment of exploration, and not a consequence of the IPO.

Unlike some prior research, this study lacks a qualitative element regarding firm innovations, such as through use of patent citations as a metric for innovation quality (see: Sørensen & Stuart, 2000; Bernstein, 2012; Aggarwal & Hsu, 2014). This precludes analyses of whether, despite stagnating patent applications, patent quality has actually improved, and thus a firm has arguably become more innovative.[14] Further, despite the focus on industries that heavily utilise patents to appropriate value from inventions, and thus limiting potential internal validity issues in measuring shifts in patenting as an appropriation strategy, potential shifts in patenting strategy that seek to use defensive or blocking patents, for example, are not accounted for. It is conceivable that the data is skewed one way or another because of different values placed on defensive patenting pre- and post-IPO.

Finally, the generalisability of this paper is limited due to the strategic use of an industry focus. For example, Sørensen & Stuart (2000) found a positive correlation between firm age and patent output in the semiconductor industry, and an inverted U-shaped relationship in the biotech industry. This suggests cross-industry differences between firms age patent output, calling into question the applicability of the results presented here to industries beyond those studied empirically.

4.3. Further Research

As always, the empirical data opens up opportunities for further research. While this study identifies exacerbated information asymmetry and potential for agency conflict as the main culprits in discouraging innovation in post-IPO firms, the empirical evidence is limited in its ability to convict them. While much has been researched into the role of these two issues in raising the cost of capital for R&D (see Hall, 2002,

[14] Bernstein, 2012, and Aggarwal & Hsu, 2014, both using patent citations, come to the conclusion that patent quality does indeed decline following an IPO.

2010), and propensity to invest in R&D (Lee & O'Neill, 2003), more research is needed. For instance, qualitative research into the role of investors in the innovation process would shed light on this issue, as would research on whether investor expertise in a firm's technology focus improves propensity to be innovative, as this would further limit information asymmetries and potential for perceived agency conflict.

Further, more research on the innovative equilibrium, or the proper allocation of resources between exploitation and exploration, as specified by (March, 1991), would shed light on this research topic. Does this stagnation or decline in innovation, both in terms of patent quantity as observed in this paper, as well as patent quality, as observed elsewhere (see: Sørensen & Stuart, 2000; Bernstein, 2012; Aggarwal & Hsu, 2014) reflect a rational and correct choice made by firms to reap benefits of prior risky investments into R&D, rather than an exogenous pressure by shareholders to pursue short-term rather than long-term objectives. It perhaps reflects recognition by larger public firms in the value in acquiring technology from outside the firm, rather than producing it in-house. In other words, these firms potentially recognise their resources are better utilised in exploiting existing knowledge, and acquiring radical new knowledge from outside the firm rather than creating it in house. Understanding this dynamic would highlight the rationality in limiting the pursuit of innovation following an IPO, and as firms age generally.

Research measuring the *ex ante* effects that the IPO has on potentially encouraging innovation would be a compelling compliment to my research as well. As Black & Gibson (1998) argue, a comprehensive stock market that provides potential for a lucrative exit event is necessary for a vibrant venture capital market. Despite the negative *ex post* effects on innovation within firms, the lack of potential for an IPO could significantly diminish overall innovation output within the United States and other countries. Without incentives to take risks on young, unproven, but potentially innovative firms, then perhaps the macro effect on overall innovation would be negative. Therefore, further research on the degree to which early-stage investments in innovative firms is driven by potential of going public would shed light on whether, overall, IPOs are a positive or negative aspect of a national system of innovation.

Finally, anecdotal cases such as Amazon exist where, despite low profit margins due to reinvestment of revenue, the firm still enjoys a high stock price. Amazon's strategy of reinvesting revenue in new technologies, rather than generating large profits (Yglesias, 2014), runs counter to the findings presented by this paper. Public market investors ostensibly appreciate the long-term value building investments in innovation that Amazon has undertaken, reflected in the stock price. Could cases such as this represent a broader sea change in how Wall Street values long-term investments in innovations, despite it generating lower profits in the short-term? Further research on this topic could prove insightful on whether or not a shift is indeed taking place, or if cases such as Amazon are unique and un-representative of the way in which investors continue to value firms.

5. Conclusion

The regression models indicate the observed firms experienced large increases in patenting output, year on year, through the pre-IPO stage until three to four years following the IPO, before stagnating or slightly declining. Though actual declines in innovation are slight, the evidence generally supports the hypothesis presented by this paper, and certainly the IPO appears to have a negative effect on innovation.

Despite growth in size and resources following the IPO, innovative output does not grow concurrently. This lends support to the theoretical background developed in the literature review that the IPO and subsequent shifts in ownership structures incentivise short-term profitability at the expense of long-term value building and innovation.

Liquidity and dispersed ownership, enabled by the IPO, exacerbates information asymmetries and potential for agency conflicts as investors have less incentive to take an active role in firm monitoring and decision-making. Investors lack the scale to efficiently gather information that would allow them to distinguish between good and bad R&D investments as well the necessity in making long-term, risky, and uncertain investments at the expense of short-term profitability. Instead, they rely on short-term earnings reports to decide whether to buy or sell equity in the firm, fostering manager myopia and reduced appetite for taking risks on innovation.

Despite the IPO's *ex post* negative impact on innovation, there are *ex ante* positive impacts in that the spectre of an IPO encourages venture capital investment, which largely goes to young, high-tech firms. This investment sows the seeds for small innovative firms to become large innovative firms. The firms studied did remain innovative over time, despite the growth trajectory of their innovative output diminishing. Thus, the IPO does appear to positively influence innovation prior to the IPO, before the effects of going public slow the growth of innovation.

What can be taken away from the empirical findings and the theoretical framework presented here is that public firms should find methods of minimising information asymmetries and perceived potential for agency conflict. While disclosing information about potential innovation is problematic, in that it limits the competitive advantage to be gained by R&D, effectively communicating to investors regarding the long-term value that investments in R&D creates, and how this affects near-term profitability, could improve investor willingness to keep their capital in a firm for the long-term. Anecdotal cases such as Amazon are encouraging. Despite low profit margins due to reinvestment of earnings into areas such as innovation, the stock price remains high, and potentially reflects investor understanding of the value of long-term investments made by the firm, despite these investments negatively impacting shortterm profitability.

Bibliography

Acs, Z., Anselin, L., & Varga, A. (2002). Patents and innovation counts as measures of regional production of new knowledge. *Research Policy*, *31*, 1069–1085. Retrieved from http://www.sciencedirect.com/science/article/pii/S0048733301001846

Aggarwal, V. A., & Hsu, D. H. (2014). Entrepreneurial Exits and Innovation. *Management Science*, *60*(4), 867–887. doi:dx.doi.org/10.1287/mnsc.2013.1801

Akerlof, G. A. (1970). The Market for “Lemons”: Quality Uncertainty and the Market Mechanism. *The Quarterly Journal of Economics*, *84*(3), 488–500.

Amit, R., Brander, J., & Zott, C. (1998). Why Do Venture Capital Firms Exist? Theory and Canadian Evidence. *Journal of Business Venturing*, *13*(6), 441–466. doi:10.1016/S0883-9026(97)00061-X

Arundel, A. (2001). The relative effectiveness of patents and secrecy for appropriation. *Research Policy*, *30*, 611–624.

Arundel, A., & Kabla, I. (1998). What percentage of innovations are patented? empirical estimates for European firms. *Research Policy*, *27*(2), 127–141. Retrieved from http://www.sciencedirect.com.ezproxy.lib.bbk.ac.uk/science/article/pii/S004873339800033X

Baker, M., Stein, J. C., & Wurgler, J. (2003). When Does the Market Matter? Stock

Prices and the Investment of Equity-Dependent Firms. *The Quarterly Journal of Economics*, *118*(3), 969–1005. Retrieved from http://www.jstor.org.ezproxy.lib.bbk.ac.uk/stable/pdfplus/25053928.pdf?acceptTC=true&jpdConfirm=true

Bernstein, S. (2012). *Does Going Public Affect Innovation? Mimeo*. Stanford University. Retrieved from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2061441

Bharath, S. T., & Dittmar, A. K. (2010). Why Do Firms Use Private Equity to Opt Out of Public Markets? *Review of Financial Studies*, *23*(5), 1771–1818. doi:10.1093/rfs/hhq016

Bhide, A. (1993). The hidden costs of stock market liquidity. *Journal of Financial Economics*, *34*(1), 31–51. doi:10.1016/0304-405X(93)90039-E

Black, B. S., & Gibson, R. J. (1998). Venture capital and the structure of capital markets: Banks versus stock markets. *Journal of Financial Economics*, *47*, 243–277. Retrieved from http://ssrn.com/abstract=46909

Bottazzi, L., Da Rin, M., & Hellmann, T. (2008). Who are the active investors? Evidence from venture capital. *Journal of Financial Economics*, *89*(3), 488–512. doi:10.1016/j.jfineco.2007.09.003

Carpenter, R. E., & Petersen, B. C. (2002). Capital Market Imperfections, High-Tech Investment, and New Equity Financing. *The Economic Journal*, *112*(477), F54–F72.

Chesbrough, H. (2006). *Open Innovation: A New Paradigm for Understanding Industrial Innovation*. (H. Chesbrough, W. Vanhaverbeke, & J. West, Eds.) (First., pp. 1–25). Oxford: Oxford University Press.

Christensen, C. M., & Overdorf, M. (2000). Meeting the Challenge of Disruptive Change. *Harvard Business Review*, (April), 66–77.

Cohen, W. M., & Klepper, S. (1996). Firm Size and the Nature of Innovation within Industries: The Case of Process and Product R&D. *The Review of Economics and Statistics*, *78*(2), 232–243. Retrieved from http://www.jstor.org/stable/2109925

Cohen, W. M., Nelson, R. R., & Walsh, J. P. (2000). *Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (Or Not)* (No. 7552). Cambridge, Massachusetts. Retrieved from http://www.nber.org/papers/w7552

Corwin, S. A., & Harris, J. H. (2001). The Initial Listing Decisions of Firms that Go Public. *Financial Management*, *30*(1), 35–55. Retrieved from http://www.jstor.org/stable/3666390

Cumming, D., & Johan, S. A. B. (2008). Preplanned exit strategies in venture capital. *European Economic Review*, *52*(7), 1209–1241. doi:10.1016/j.euroecorev.2008.01.001

Darby, M. R., & Zucker, L. G. (2003). *Grilichesian Breakthroughs: Inventions of Methods of Inventing and Firm Entry in Nanotechnology* (No. 9825) (pp. 1–62). Cambridge, Massachusetts. Retrieved from http://www.nber.org/papers/w9825

Ellul, A., & Pagano, M. (2006). IPO Underpricing and After-Market Liquidity. *Review of Financial Studies*, *19*(2), 381–421. doi:10.1093/rfs/hhj018

Fang, V. W., Tian, X., & Tice, S. (2013). Does Stock Liquidity Enhance or Impede Firm Innovation? *Journal of Finance (forthcoming)*. doi:10.1111/jofi.12187 Faure-Grimaud, A., & Gromb, D. (2003). Public Trading and Private Incentives. *Review of Financial Studies*, *17*(4), 985–1014. doi:10.1093/rfs/hhh002

Ferreira, D., Manso, G., & Silva, A. C. (2012). Incentives to Innovate and the Decision to Go Public or Private. *Review of Financial Studies (Forthcoming)*, (May). Retrieved from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1568268

Field, L. C., & Hanka, G. (2001). The Expiration of IPO Share Lockups. *The Journal of Finance*, *56*(2), 471–500.

Filippetti, A., & Archibugi, D. (2011). Innovation in times of crisis: National Systems of Innovation, structure, and demand. *Research Policy*, *40*(2), 179–192. doi:10.1016/j.respol.2010.09.001

Fluck, Z., Holtz-Eakin, D., & Rosen, H. (1998). *Where Does the Money Come From* (No. 191) (pp. 1–33). Syracuse, New York.

Franks, J., & Brennan, M. (1997). Underpricing, ownership and control in initial public offerings of equity securities in the UK. *Journal of Financial Economics*, *45*, 391–413.

Garfinkel, J. A. (1993). IPO Underpricing, Insider Selling and Subsequent Equity Offerings: Is Underpricing a Signal of Quality? *Financial Management*, *22*(1), 74–83. Retrieved from http://www.jstor.org/stable/3665967

Graham, J. R., Harvey, C. R., & Rajgopal, S. (2005). The Economic Implications of Corporate Financial Reporting. *Journal of Accounting and Economics*, *40*(1-3), 3–73. doi:10.1016/j.jacceco.2005.01.002

Hall, B. H. (1990). *The Impact of Corporate Restructuring on Industrial Research and Development* (pp. 85–135).

Hall, B. H. (1994). Corporate Restructuring and Investment Horizons in the United States, 1976-1987. *Business History Review*, *68*(1), 1976–1987.

Hall, B. H. (2002). The Financing of Research and Development. *Oxford Review of Economic Policy*, *18*(1), 35–51. doi:10.1093/oxrep/18.1.35

Hall, B. H. (2010). The Financing of Innovative Firms. *Review of Economics and Institutions*, *1*(1), 1–30. doi:10.5202/rei.v1i1.4

Hall, B. H., Griliches, Z., & Hausman, J. A. (1986). Patents and R and D: Is There a Lag? *International Economic Review*, *27*(2), 265–283.

Hall, B. H., Jaffe, A. B., & Trajtenberg, M. (2001). *The NBER Patent Citations Data File: Lessons, Insights and Methodological Tools* (No. 8498). Cambridge, Massachusetts. Retrieved from http://www.nber.org/papers/w8498

Heeley, M. B., Matusik, S. F., & Jain, N. (2007). Innovation, Appropriability and the Underpricing of Initial Public Offerings. *Academy of Management Journal*, *50*(1), 209–225. Retrieved from http://amj.aom.org/content/50/1/209.short

Hellmann, T., & Puri, M. (2000). The Interaction Between Product Market and Financing Strategy: The Role of Venture Capital. *The Review of Financial Studies*, *13*(4), 959–984.

Helwege, J., Pirinsky, C., & Stulz, R. M. (2007). Why Do Firms Become Widely Held ? An Analysis. *The Journal of Finance*, *62*(3), 995–1028.

Holmström, B. (1989). *Agency Costs and Innovation* (No. 214). *1988* (pp. 1–37). Stockholm. Retrieved from http://hdl.handle.net/10419/94833

Hsu, D., & Ziedonis, R. H. (2007). Patents as Quality Signals for Entrepreneurial Ventures. In *DRUID Summer Conference 2007* (pp. 1–42). Copenhagen.

Jensen, M. C. (1986). Agency costs of free cash flow, corporate finance, and takeovers. *The American Economic Review*, 323–329. Retrieved from http://lib.cufe.edu.cn/upload_files/file/20140522/3_20140522_36 Jensen, Michael C., 1986, Agency costs of free-cash-flow.pdf

Jensen, M. C. (1997). Eclipse of the Public Corporation. *Harvard Business Review*, (September-October 1989 (rev. ed.)).

Kaplan, S. N., & Strömberg, P. (2008). *Leveraged Buyouts and Private Equity* (No. 14207) (pp. 1–35). Cambridge, Massachusetts. Retrieved from http://www.nber.org/papers/w14207

Kim, W., & Weisbach, M. (2008). Motivations for public equity offers: An international perspective. *Journal of Financial Economics*, *87*(2), 281–307. doi:10.1016/j.jfineco.2006.09.010

Kline, S. J. (1985). Innovation is not a linear process. *Research Management*, *28*(4), 36–45.

Kortum, S., & Lerner, J. (2000). Assessing the Contribution of Venture Capital to Innovation. *RAND Journal of Economics*, *31*(4), 674–692. Retrieved from http://www.jstor.org/stable/2696354

Kothare, M. (1997). The effects of equity issues on ownership structure and stock liquidity: A comparison of rights and public offerings. *Journal of Financial Economics*, *43*(1), 131–148. Retrieved from http://www.sciencedirect.com/science/article/pii/S0304405X96008926#

Kroll, M., Walters, B. A., & Le, S. A. (2007). The Impact of Board Composition and Top Management Team Ownership Structure on Post-IPO Performance in Young Entrepreneurial Firms. *Academy of Management Journal*, *50*(5), 1198–1216.

Lee, P. M., & O'Neill, H. M. (2003). Ownership Structures and R&D Investments of U.S. and Japanese Firms: Agency and Stewardship Perspectives. *Academy of Management Journal*, *46*(2), 212–225. Retrieved from http://www.jstor.org/stable/30040615

Lerner, J., Sorensen, M., & Strömberg, P. (2011). Private Equity and Long-Run Investment : The Case of Innovation. *The Journal*, *66*(2), 445–477. Retrieved from http://web.b.ebscohost.com.ezproxy.lib.bbk.ac.uk/ehost/detail?sid=c3434845-7a92-46cb-a66c-7c5618020dcc%40sessionmgr113&vid=1&hid=119&bdata=JnNpdGU9ZWhvc3QtbGl2ZQ%3d%3d#db=buh&AN=59527260

Levin, R. C., Klevorick, A. K., Nelson, R. R., & Winter, S. G. (1988). *Appropriating the Returns from Industrial R&D* (No. 862) (pp. 1–81). New Haven. Retrieved from http://dido.econ.yale.edu/P/cd/d08b/d0862.pdf

Loughran, T., & Ritter, J. R. (1995). The New Issues Puzzle. *American Finance Association*, *50*(1), 23–51.

March, J. G. (1991). Exploration and Exploitation in Organizational Learning. *Organization Science*, *2*(1), 71–87. Retrieved from https://sjbae.pbworks.com/f/march+1991.pdf

Mason, C. M. (2007). Informal Sources of Venture Finance. In S. Parker (Ed.), *The Life Cycle of Entrepreneurial Ventures* (Volume 2., Vol. 2, pp. 259–299). Springer.

Michaely, R., & Roberts, M. R. (2011). Corporate Dividend Policies: Lessons from Private Firms. *Review of Financial Studies*, *25*(3), 711–746. doi:10.1093/rfs/hhr108

Niosi, J. (1999). Fourth-Generation R&D: From Linear Models to Flexible Innovation. *Journal of Business Research*, *45*(2), 111–117.

Pagano, M., Panetta, F., & Zingales, L. (1998). Why Do Companies Go Public? An Empirical Analysis. *The Journal of Finance*, *53*(1), 27–64.

Pham, P. K., Kalev, P. S., & Steen, A. B. (2003). Underpricing, stock allocation, ownership structure and post-listing liquidity of newly listed firms. *Journal of Banking & Finance*, *27*(5), 919–947. doi:10.1016/S0378-4266(02)00241-8

Popov, A., & Roosenboom, P. (2009). *Does Private Equity Investment Spur Innovation? Evidence from Europe* (No. 1063) (Vol. 1, pp. 1–36). Retrieved from http://www.fma.org/Turin/Papers/Does_Private_Equity_Spur_Innovation_Evidence_from_Europe.pdf

Prowse, S. D. (1998). The Economics of the Private Equity Market. *Economic Review-Federal Reserve Bank of Dallas*, (Third/Quarter), 21–35.

Rappaport, A. (2005). The Economics of Short-Term Performance Obsession. *Financial Analysts Journal*, *61*(3), 65–79. Retrieved from http://cmsu2.ucmo.edu/public/classes/young/Guidance Research/The Economics of Short-Term Performance Obsession.pdf

Ritter, J. R., & Welch, I. (2002). A Review of IPO Activity, Pricing, and Allocations. *Journal of Finance*, *57*(4), 1795–1828. Retrieved from http://web.ebscohost.com.ezproxy.lib.bbk.ac.uk/ehost/pdfviewer/pdfviewer?sid=b06d11a7-464a-4e44-ae11-6d1717651232@sessionmgr115&vid=2&hid=121

Schwienbacher, A. (2008). Innovation and Venture Capital Exits. *The Economic Journal*, *118*(November), 1888–1916.

Sørensen, J. B., & Stuart, T. E. (2000). Aging, Obsolescence, and Organizational Innovation. *Administrative Science Quarterly*, *45*(1), 81. doi:10.2307/2666980

Stein, J. C. (1989). Efficient Capital Markets, Inefficient Firms: A Model of Myopic Corporate Behaviour. *The Quarterly Journal of Economics*, (November), 655–669. Retrieved from http://qje.oxfordjournals.org/content/104/4/655.full.pdf

Tylecote, A., & Conesa, E. (1999). Corporate Governance, Innovation Systems and Industrial Performance. *Industry & Innovation*, *6*(1), 25–50.

Wright, M., & Robbie, K. (1998). Venture Capital and Private Equity: A Review and Synthesis. *Journal of Business Finance & Accounting*, *25*(5 & 6), 521–570. Retrieved from http://onlinelibrary.wiley.com/store/10.1111/1468-5957.00201/asset/1468-5957.00201.pdf?v=1&t=hxyqfyz4&s=f713490324b9121e809516a1964607b87603de9f

Yglesias, M. (2014, January). The Prophet of No Profit. *Slate*. Retrieved from http://www.slate.com/articles/business/moneybox/2014/01/amazon_earnings_how_jeff_bezos_gets_investors_to_believe_in_him.2.html

Zheng, S. X., & Li, M. (2008). Underpricing, ownership dispersion, and aftermarket liquidity of IPO stocks. *Journal of Empirical Finance*, *15*(3), 436–454. doi:10.1016/j.jempfin.2007.08.001

Zingales, L. (1995). Insider Ownership and the Decision to Go Public. *Review of Economic Studies*, *62*(3), 425–448. doi:10.2307/2298036

Appendix – Data Sources

1. IPO Dates

The list of public companies in the biotechnology, pharmaceutical, and medical supplies industries that conducted an initial public offering (IPO) between 1979 and 2002 (including the date of the IPO) was gathered through the Osiris database of international listed companies. Several results from the Osiris search lacked an IPO date. The author searched popular press in order to determine a date if possible; this was not always successful so many firms were dropped from the analysis. Osiris can be accessed at: http://osiris.bvdinfo.com

2. Patent Figures

Google Patent Search was used to gather observed patent grants for the three years preceding, through nine years following the IPO. Search tools applied various filters. Filing status was set to granted patents, as opposed to applications. Searches were conducted of patents registered with the United States Patent Office so as to avoid duplicate intellectual property being registered with several international patent offices. All patent types were considered. The time range was sorted according to the filing date, as opposed to the patent grant date, to reflect the closest time period between innovation and new knowledge generation and the resulting patent. The firm name was the first search conducted under “original assignee”. Subsequent searches for alternative assignee names were conducted via search engine, as well as within Google Patent Search by looking for inventor crossover. Often when two or more inventors were common in a patent under a different original assignee name in years immediately preceding first available patent data from the original search, this indicated a name change. This, however, was cross-referenced with popular press as well as the company’s own website in order to determine whether they operated under a different name. Several firms from the Osiris search yielded zero patent observations for the observed time period, and in many cases a search to determine whether they had operated under a different name did not turn up any results either, and so they were dropped from the analysis. Google Patent Search can be accessed at:

http://www.google.com/patents

3. Raw Data

The raw data entered into SPSS for statistical analysis was compiled exclusively by the author. Patent figures were checked through twice in order to ensure accuracy. The raw data is accessible on spreadsheet via Google Drive at:

http://goo.gl/Oi86x7