A SPATIAL AND SECTORAL ANALYSIS
OF U.S. TECHNOLOGICAL INNOVATION
AND VENTURE CAPITAL INVESTMENT PERFORMANCE

A paper

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A Spatial and Sectoral Analysis of U.S. Technology Innovation and Venture Capital Investment Performance[1]

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Abstract

The economic impact of venture capital on the U.S. economy is significant. Global Insight (2007) estimated total revenue of venture-backed companies to be $2.3 trillion (17.6% of U.S. GDP) and 10.4 million jobs (9.1% of U.S. private sector employment) resulting from VC-backed IPO and M&A exits – the key determinants of venture capital performance. Thus it is no surprise that policy makers see venture capital as an important instrument of regional economic development.

A recent study by Chen et al (2010) assessed the geographic concentration of both venture capital firms and venture capital-financed companies in specific metropolitan areas. Venture capital firms were found to be located in regions with high success rates of venture capital-backed investments as measured by the incidence of exits. Venture capital firms based in locales that were venture capital centers were found to outperform regardless of investment stage or location.

The study however paid little attention to the influence of technological innovation on venture capital performance, arguably the most important of all Schumpeterian innovations for technology-based firms. This study seeks to address this specific knowledge gap in venture capital research and practice. It builds on resource-based view (RBV) and knowledge-based view theories which argue that technological innovation is a strategic resource of the firm that can provide competitive advantage and produce superior performance.

This research paper is based on matched data compiled from VentureXpert™, Delphion™ and NBER/USPTO databases. The resulting unique and proprietary dataset consists of 1020 VC-backed US technology company IPO exits across all technology sectors in the 20 years from 1980-2000. The relation between technological innovation of VC-backed firms and venture capital exit performance is examined with a focus on the influence of spatial and sectoral factors which have been found to be meaningful predictors in theories (i.e. regional growth, industrial, cluster and evolutionary theories) explaining the uneven distribution of technological innovation. As predicted by RBV theory technology firms engaged in patenting activity attracted more VC investors but experienced however lower IPO exit intensity, longer time-to-exit and lower IPO multiples. Results show that sectoral and spatial factors influence the patenting activity and investment performance of VC-backed technology firms. *Patenting activity* is shown to vary significantly across sectors but not across regions. Dependent variables *total VC invested* and *VC investor efficiency* are shown to vary significantly across both regions and sectors whilst *IPO value* is shown to vary significantly across sectors but not across regions.

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INTRODUCTION

Venture capital is usually provided for early-stage, high-potential, growth companies in the interest of generating a return through an eventual realisation event such as an IPO (Initial Public Offering) or trade sale of the company. Venture capital is above all the capital that VCs ("venture capitalists") invest and actively manage on behalf of investors. VCs perform three principal functions: 1. they screen potential investments and select companies to invest in, 2. they monitor investee companies and provide value-added services for them, and 3. they exit investments by selling their stake to public markets or to another buyer (Metrick, 2007). The main goal of this paper is to examine the influence of technological innovation geography on the performance of two of these important functions performed by VCs: selection and exiting which define the beginning and the end of the venture capital cycle.

Venture capital firms are known to invest in early-stage technology companies where high information asymmetries between investors and managers are exacerbated by uncertain future prospects. Venture capital firms, with sector-specific insider knowledge, play a crucial role in managing these information asymmetries. These specialist venture capital firms are characterised by investment selection behaviour clustered around technology. Moreover successful VC-backed technology firms that go public rarely change or make a huge leap from their initial technological innovation (Kaplan et al, 2009). This suggests that it is very important that a VC picks a good business with strong technological innovation during the screening process. Conversely it is also important that technology firms signal their ability to innovate to VCs if they wish to secure venture capital funding. Accordingly studies have shown that technology investors give much weight to selection criteria related to technological innovation e.g. protection of intellectual property, platform and uniqueness (Clarysse et al, 2004). Previous studies have shown how U.S. VC firms displayed a high level of agglomeration due to the information intensive nature of the investment process and the importance of venture capital networks in locating investments, mobilizing resources, and establishing start-ups (Florida and Kenney, 1988). However these regional studies, primarily focused on first-order agglomeration externalities (amongst VC firms), did not inform us about how the geography of technological innovation may influence venture capital investment selection behaviour. This paper addresses this empirical gap in our knowledge of VCs' investment selection behaviour.

Exiting in general has been rightly identified as a promising area for further venture capital research (Gompers and Lerner, 2004). Little research has been conducted to determine how technological innovation may contribute to the investment performance of the young technology firm, be via an

IPO or a trade sale, let alone the geography of technological innovation. It is often argued that technology VC firms exist primarily to maximise investment in technology innovation. Earlier studies have argued that venture capital can spur technological innovation (Kortum and Lerner, 2000). However a different reality emerged from other studies which have concluded that venture capital actually thwarts technological innovation due to the life cycle of venture funds (Stuck and Weingarten, 2005). U.S. regional studies have concluded that geography is related to venture capital firm performance. Venture capital firms, based in locales that are venture capital centres, outperformed regardless of the stage of the investment (Chen et al, 2010). However these regional studies failed to consider technological innovation as an explanatory variable to explain regional variations in investment performance and focused on the VC firm as the unit of analysis as opposed to the investee firm, locus of technological innovation. Moreover results failed to consider the impact of time on venture capital investment performance. The paper addresses the impact of technological innovation geography on venture capital investment performance as an important empirical knowledge gap in the literature.

This research builds on resource-based view theory of the firm (Penrose, 1959; Barney, 1991) including the more specific knowledge-based view (Grant, 1996; Spender, 1996) and argues that technological innovation is a strategic resource of the firm that can provide competitive advantage (Porter, 1979, 1985) and produce superior performance (Arrow, 1962; Griliches, 1981; Romer, 1986, 1990; Geroski, 1993; Granstrand, 1999). RBV has been found to be an effective conceptual approach for explaining how a critical resource, such as technological innovation, can affect the firm's evolution and growth. By examining firms' technological innovation over time, from early stage to IPO, light can be shed on the nature of such critical resource and the periods in which it is critical. Some U.S. regions may be better endowed with technological resources which may, in turn, help technology firms based in these locales achieve superior venture capital selection and investment performance. The same can be said of some industry sectors which may have a higher propensity to innovate than others. Thus for RBV to explain how technological innovation geography may impact venture capital selection and investment performance one must control for sectoral differences. Moreover the venture capital life cycle may hamper technological innovation and limit RBV's explanatory power. VCs are generally constrained by time and money in order to ensure acceptable returns to VC fund investors. In these circumstances technological innovation may not fully develop and be commercially exploited by the time the technology firm must exit via an IPO. One can see how this research may lead to conceptual advances and a possible revision of a "RBV theory under constraints".

The paper goes further than recent regional venture capital studies (Chen et al, 2010) and studies evaluating the impact of sector-specific patenting activity on the venture capital cycle (Cockburn and MacGarvie, 2009; Mann and Sager, 2007). The relationship between technological innovation and venture capital selection and investment performance is analysed together with the moderating influence of spatial (Acs et al., 2002; Simmie, 2005) and sectoral (Malerba et al., 1996, 1997, 2002) factors as these factors have been found to be meaningful predictors in theories (i.e. regional growth, industrial, cluster and evolutionary theories) explaining the uneven distribution of technological innovation. This is an empirical study which examines the impact of technological innovation geography on two critical activities of VCs: venture capital selection and exit. The firm is the basic unit of analysis since technological innovation takes place and is protected and exploited at firm level.

The paper is organized as follows. The next section provides an overview of the venture capital industry. The following section discusses the related literature and hypotheses. This is then followed by details about methodology and the construction of the data. The following section presents results. The final section concludes with a discussion of study results and limitations together with implications for further work.

VENTURE CAPITAL INDUSTRY

Venture capital is a truly global industry. According to PWC *Global Private Equity Report* (2006) approximately US$136 billion of private equity and venture capital was invested globally in 2005. This is equivalent to 0.3% of the world's gross domestic product. A record US$272 billion of funds were raised globally in 2005. Limited partners included pension funds, banks, funds of funds, insurance companies, corporate investors and government agencies. Technology investments totaled US$47 billion in 2005 – 35% of total investment. Five countries accounted for nearly three quarters of global private equity and venture capital: US (34.1%), UK (20.5%), China (6.5%), France (6.3%) and Japan (5.8%). The US total of $47.6 billion was split 50-50 between venture and buyout investments, in contrast with only 32% of Europe total of $55.1 billion invested in ventures. U.S. technology venture investments of US$24 billion represented more than 50% of global venture capital investment in technology. O'Sullivan (2006) reported even greater variations in early-stage venture investment as percentage of GDP where US, Europe and UK investment in early-stage venture in 1999 stood at 0.056%, 0.036% and 0.020% of GDP, respectively.

In high technology US venture capital was even more dominant accounting for approximately 50% of global investments. Cumulative long-term (20-yr) fund performance of 1,860 US venture funds with an aggregate capitalization of $678 billion outperformed the Nasdaq Composite Index by as much as 7.0% with an average pooled IRR[2] of 16.4%, providing adequate compensation for the liquidity risk.

US technology investments in the 25 years from 1980-2005 revealed that a total of 70,856 deals valued at $437.7 billion were made by 13,894 VC firms in 25,614 technology companies in six major industry groups. Data show that US venture capital investors largely favoured information and communication technology (ICT) over life sciences including biotech with more than 85% of total technology investments in ICT during the period. Average investments ranged between $15 million and $30 million per company depending on technology sector.

Venture capital plays an important role in the U.S. economy. The National Venture Capital Association (NVCA).commissioned a study by Global Insight (2007) to evaluate the role of venture capital: *Venture Impact: The Economic Importance of Venture Capital Backed Companies to the U.S. Economy*. Statistics based on a database of 23,580 venture capital backed companies demonstrated the enormous contribution of venture capital backed companies to U.S. jobs, sales, economic growth, and technological progress. Total revenue of venture-backed companies was estimated to be $2.3 trillion (17.6% of U.S. GDP) and 10.4 million jobs (9.1% of U.S. private sector employment.). Moreover revenue and employment growth rates of venture-backed companies were approximately double that of the economy as a whole. The report also highlighted both spatial and sectoral effects of venture capital. Employment in venture-backed companies was shown to be unevenly distributed with five states accounting for more than 50% of total job creation: California, Texas, Pennsylvania, Massachusetts and Georgia. Similarly some U.S. industry sectors such as computer and peripherals, software and telecommunications were shown to be dominated by venture-backed companies with share of total industry revenue representing 78.3%, 38.9% and 35.4%, respectively.

M&A (Merger and Acquisition) and IPO exits define the performance of venture capital investments. According to Thomson Financial the 25 years from 1980-2005 saw 4,850 exits out of 25,614 U.S. venture-backed technology companies; 2,462 went public on U.S. exchanges at an average post offer valuation of $207 million whilst 2,388 exited through the M&A market for an average disclosed deal size of $129 million. Considering that average technology venture capital investments ranged between $15 million and $30 million per company during that period there is little doubt that these exits provided VC investors with a handsome return.

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[2] The IRR is the interim net return (after all fees and carried interest) earned by investors (Limited Partners) from the fund from inception. The pooled IRR is obtained by taking cash flows from inception together with the Residual Value of each fund and aggregating them into a pool as if they were a single fund.

The U.S. venture capital market offers a long, unique and well-documented history of success in technology venture capital investing. These characteristics of U.S. venture capital combined with the availability of reliable longitudinal data on VC performance (and patents) make the U.S. venture capital market the logical choice for a thorough investigation of the relation between firm's technological innovation and venture capital performance.

VENTURE CAPITAL SELECTION & EXIT, INNOVATION AND GEOGRAPHY

A review of the related literature reveals two main strands: the literature on innovation and the literature on venture capital. In the review of the innovation literature the emphasis is put on economic studies of innovation and related theories of the firm and the clustering influence of spatial and sectoral factors. In the review of the venture capital literature the emphasis is put on venture capital investment selection and exit performance and the extent to which geography actually matters.

Theories of the Firm

Conceptual underpinnings for this research are grounded in classical resource-based view and competitive strategy theories of the firm. Technological innovation is, arguably, one of the most potent resource technology-based firms (TBFs) have to sustain long term competitive advantage over large established incumbents, and in doing so, earn superior returns.

Penrose (1959) first suggested that the returns earned by firms could largely be attributed resources they held. Building upon RBV Barney (1991), in his seminal paper *Firm Resources and Competitive Advantage,* identified four empirical indicators of the potential of the firm resources to generate sustained competitive advantage – *value*, *rareness*, *imitability* and *substitutability.* Moreover, Barney's model assumed heterogeneity between resources the firm controls and that these resources were not perfectly mobile across firms, implying that heterogeneity could be long lasting. *Resources* (e.g. assets, capabilities, processes, information, knowledge, etc) are defined as strengths firms can use to conceive their strategies and *sustained competitive advantage* as something the firm has when it is implementing a unique value creating strategy not reproducible by current or potential competitors (in spite of their effort to do so). If these conditions hold, the firm's bundle of resources can assist the firm sustaining above average returns. Although Barney's model was developed for a wide range of resources of the firm one would struggle to find a better list of attributes than these empirical indicators to characterise a firm's technology innovations protected by strong international patents.

One of RBV's main criticism is its neglect of external factors concerning the industry as a whole. Porter (1979, 1985) addressed these limitations and developed competitive strategy theory to help understand internal and external sources of sustained competitive advantage at the industry level. By conducting an industry structure analysis, or SWOT analysis (i.e. strengths, weaknesses, opportunities and threats), strategic resources and capabilities available or deficient within firms could be identified within an industry structure.

In support of the RBV approach authors (Grant, 1996; Spender, 1996) have argued that knowledge and the firm's ability to generate it were at the core of the theory of the firm and provided further insights above and beyond RBV theories and competitive strategy theory. According to the author technological knowledge (that is, knowledge that describes the functions and interactions of natural and artificial things) can be individual explicit (i.e.. individual skills pertaining to a particular technology that can be codified e.g. a patent), individual tacit (i.e. individual skills pertaining to a particular technology that is personal), collective explicit (e.g. standard operating procedures), or collective tacit (e.g. an organization's routines and culture regarding technology). Each of these technological knowledge dimensions can be the source of competitive advantage and value creation. In agreement with Grant and Spender, Granstrand (1998) defined technology as a knowledge resource sharing the general characteristics of knowledge but with additional features such as being protectable by patents, giving them strong economies of scale, scope, speed and space resulting in a greater ability to create a sustainable competitive advantage for the firm and superior performance for investors.

Venture Capital Investment Selection

Selection criteria used by venture capitalists (VCs) for screening and evaluating investment opportunities are of utmost importance. They define chances of success, and ultimately, investment performance. A better understanding of these criteria used for selecting successful ventures can contribute to improving the success rate of new ventures in the future. Of particular interest for this research is the importance given to technological innovation amongst selection criteria used by VCs.

VC selection practices are not as homogeneous across all investment situations and VCs as one might think (Shepherd et al., 1999). Selection behaviour can be influenced by preferences and experiences derived from a different investment focus (e.g. stage of investment, technology, etc). In a study of European early stage technology VCs Clarysse et al. (2004) found that "technology" investors gave more weight to innovation criteria such as protection of intellectual property (IP), uniqueness and platform technology than "people" or "financial" investors. Authors also found that business opportunities with innovative technologies are more likely to be financed by technology VC funds backed by public money because of their impact on technological renewal and economic growth. Similarly Roberts and Barley (2004) found that when VCs are asked how they evaluate venture investment opportunities two crucial selection criteria were found to be standing above all others: the idea (i.e. innovation) and management. The relative importance of a young company's innovative business idea and management team to company's success has been the subject of an ongoing debate amongst VCs. This debate (Kaplan et al, 2009) is often characterized as whether one should bet on the jockey (entrepreneur, management) or bet on the horse (technological innovation, business idea).

Other studies concluded similarly that whilst human capital needed be monitored by VCs to ensure the good management of new ventures it should not be a decision criterion for financing them in the first place (Jain and Tabak, 2008; Baum and Silverman, 2004).

> "When a management team with a reputation for brilliance tackles a business with a reputation for bad economics, it is the reputation of the business that remains intact[3]."

Sorensen (2007) showed that *sorting* (i.e. business selection) had a significant impact on IPO rates, an important measure of VC performance. This followed both from the direct influence of more experienced VCs and from sorting in the market, which lead experienced VCs to invest in better companies.

A related strand of research in the literature is concerned with the endogenous influence of venture capital on TBF innovation. Kortum and Lerner (2000) examined the influence of venture capital on innovation in the US across twenty industries over three decades and found that increases in venture capital activity are associated with higher patenting rates. Whilst the ratio of venture capital to R&D is less than 3% authors found that venture capital accounted for more that 8% of industrial innovations during the period. In a later study however Caselli et al. (2006) revisited Kortum and Lerner's conclusions and questioned whether VCs are catalysts for innovation or simply exploit it. Authors investigated whether innovation was present when venture capitalists decided to invest and then analysed the behaviour of venture capitalists after investing. Results indicated that VC investments were based on researching *ex ante* companies with high growth prospects and strong innovation in place, consistent with RBV theory. In contrast with the conclusions of Kortum and Lerner's study *ex post* VC investment behaviour was found to be characterised by the trading of former innovations, rather than developing new innovative projects. Such opposed conclusions are not likely to be only attributable to differences in datasets. Evidence that venture capital actually spurs technological innovation (as measured by patenting activity) is at best mixed. The previous section on the VC industry clearly highlighted how venture capitalists are under constant pressure from institutional investors (i.e. limited partners) in VC funds to deliver successful exits within a reasonable timeframe, a fundamental requirement of VC performance. These conditions make it difficult, if not impossible, for VCs not to focus on the rapid commercial development of young firms and to venture into long term, speculative technological innovations which may, or may not be patentable, let alone commercially successful. Thus findings and conclusions from Caselli et al. (2006) seem *a priori* to be more plausible.

In view of this evidence it is reasonable to conclude that resource-based view (RBV) theory of the firm provides a strong foundation for modelling VC investment selection. RBV has inspired much of the literature on unique, differentiated and valuable resources and capabilities required by the small technology firm to sustain competitive advantage over larger incumbents. RBV is also most appropriate for *sorting* (Sorensen, 2007) technological innovation and critical non-human assets such as patent and intellectual property. RBV argues that firms possess resources, a subset of which enable them to achieve competitive advantage that lead to superior long-term performance (Penrose 1959; Barney 1991). That advantage can be sustained over longer time periods to the extent that the firm is able to protect against resource imitation, transfer, or substitution. Several empirical studies of VC investment selection using the theory have strongly supported the resource-based view theory.

Venture Capital Exit and Investment Performance

Venture capital finance differs from corporate finance decisions in many important ways. Smith and Smith (2004) highlighted the following:

i. the extent of managerial involvement by VC investors,
ii. the effects of information problems on firm's ability to undertake a project,
iii. the importance of harvesting as an aspect of valuation and the investment decision.

Differences between venture and corporate finance can arise from the magnitude and importance of the information problem between inside and outside investors. There is abundant literature about the central role VCs play in minimizing information asymmetries (Amit et al., 1998). Gompers (1995) examined the structure of staged venture capital investments when agency and monitoring costs exist. He found that expected agency costs increased as assets became less tangible, growth options increased, and asset specificity rose. Venture capitalists concentrated investments in early stage and high technology companies where informational asymmetries were highest. Decreases in industry ratios of tangible assets to total assets, higher market-to-book ratios, and greater R&D intensities lead to more frequent monitoring. Venture capitalists continuously gathered information and maintained

[3] http://en.wikiquote.org/wiki/Warren_Buffett

the option to discontinue funding projects with little probability of going public[4]. In practice, venture capital contracts which may include cash flow rights, board rights, voting rights, liquidation rights, and other control rights are used by the entrepreneur and VC investors to realise the advantages of VC financing and mitigate agency costs and information problems (Kaplan and Stromberg, 2003; Admati and Pfleiderer, 1994).

Exiting, the final stage of the VC investment process is a most critical component of valuation and evaluation in initial investment decisions. In corporate finance, investment opportunities are evaluated based on ability to generate free positive cash flow. Investing in new ventures is different. New venture investments normally are not liquid and often do not generate any significant free cash flow for several years. Thus VCs evaluate opportunities based on the expectation of a liquidity event that will enable them to realise a return. Because of the importance of liquidity events, they are generally forecast and factored into valuation of the investment. Going public (via an Initial Public Offering, IPO) and private sale of the venture to another firm (i.e. Merger and Acquisition, M&A) are, by far, the most common exiting alternatives in the U.S.

From the VC's perspective liquidity events ("exits") is the true and only measure of performance in venture capital investing and IPOs and M&As are the most common form of venture capital exits. Thus this research focuses on one of these exit options, namely IPOs. However the specific aim of this research paper is to examine the relationship between technological innovation geography and venture capital investment performance and the literature on this point is rather limited. It lacks organisation, creating much opportunity for further research. This apparent lack of interest is somewhat surprising given the interdependence of innovation and finance. Innovation is considered a critical driver of economic growth and value creation, and venture capital is an important channel through which innovation is financed.

A few studies however provide a good insight into the difficulties associated with exiting. Metrick (2007) analysed state of the art panel data from the Sand Hill Econometrics (SHE) database and found that by ten years after the initial VC investment 23.2 percent of all companies had an IPO, 38.0 percent had been acquired, 14.3 percent were defunct, and 24.6 percent were still private. IPO exits resulted in significantly higher investment multiples than M&A exits. A larger majority of exits, i.e. 84-95%, were found to be via an IPO or a trade sale (Giot and Schwienbacher, 2007). As expected, significant variations were found across various competitive industries and different investment stages (Huyghebaert et al., 2004). In a related study Bach (2002) took a resource-based view of

[4] Guler (2007) however found that VCs were less likely to terminate unsuccessful investments as they participate in more rounds of financing.

antecedents of venture IPO performance (i.e. Tobin's q[5]) and found the technology resource (i.e. # patents filed) to be a significant antecedent of IPO performance. Similarly, linking data relating to venture capital financing of software start-up firms with data concerning the patents obtained by those firms, Mann and Sager (2007) found significant and robust positive correlations between patenting and several variables measuring the firm's performance (including number of rounds, total investment, exit status, receipt of late stage financing, and longevity). Patenting practices were found to vary considerably among the sub-sectors of the software industry, suggesting the influence of sectoral factors..

Geography of Innovation

It is reasonable to believe that some regions or sectors of the U.S. economy may be more innovative than others. This means that innovation intensity may be high and frequent, perhaps more radical, innovations may emerge from firms operating in those regions or sectors. Similarly one might expect venture capital, the finance of innovation, to be distributed unevenly across U.S. regions and sectors. This would be consistent with Schumpeter's innovation economics which positioned knowledge, technology, entrepreneurship, and innovation as the key ingredients of economic growth. Schumpeter (1942) believed that what primarily drives economic growth is not capital accumulation, as claimed by neoclassical economists, but innovation. Thus the central goal of economic policy should be to spur greater innovation. Schumpeter (1934, p.66) argued that economic development emerged when "new combinations appear discontinuously". According to Schumpeter new combinations might include new forms of production, products, and business models to expand wealth. This research is solidly grounded in Schumpeter's ideas.

In the last 25 years the U.S. economy developed a wide array of new technologies, particularly information technologies, and used them widely. Despite regional innovation policy however there is little doubt that the distribution of U.S. technological innovation (hence propensity for patenting opportunities) and venture capital remain largely uneven. In this section innovation clustering is discussed under three themes: (i) spatial factors, (ii) sectoral.factors, and (iii) spatial-sectoral VC factors.

Spatial factors. Empirical studies have increasingly shown that there is a distinctive geography of innovation. Porter (1998) made a more substantial contribution to cluster theory than Schumpeter focusing primarily on the spatial dimension. He argued that clusters, he defined as geographic concentrations of interconnected companies and institutions in a particular field, were a striking feature of virtually every national, regional, state, and even metropolitan economy, especially in more

[5] Tobin's q is a ratio, developed by James Tobin, comparing the market value of a company's stock with the value of a company's equity book value.

economically advanced nations. Being part of a cluster, he argued, allows companies to operate more productively in sourcing inputs; accessing information, technology, and needed institutions; coordinating with related companies; and measuring and motivating improvement. In addition to enhancing performance, Porter argued that clusters play a vital role in a company's ongoing ability to innovate and new companies are more likely to grow up within an existing cluster rather than at isolated locations. He went on to single-handedly mapped key clusters of the US economy including venture capital concentrations in Silicon Valley and Boston.

Sectoral Factors. Evidence of the sectoral dimension of innovation is abundant. As pointed out by Fagerberg (2006) the degree of technological innovation of an industry or sector has attracted much interest and several attempts to develop ways of classifying industries and sectors have followed accordingly. In an extensive analysis of data on 2000 significant innovations in Britain since 1945 Pavitt (1984) sought to explain sectoral patterns of technical change. In his taxonomy of innovations Pavitt identified three high-tech sectors of the economy. He labelled them as follows:

i. "science-based" characterised by firms with strong links to science (high R&D intensity and technical means of appropriation e.g. patents) focused on product/process performance innovation (e.g. electronics and chemical),
ii. "production-intensive" sector characterised by firms focused on cost-cutting process/product innovation using technical means of appropriation such as patents, etc (e.g. bulk materials, automotive, consumer durables), and
iii. "supplier-dominated" based on engineering (low R&D intensity and non-technical means of appropriation e.g. trademarks) and characterised by firms focused on cost-cutting process innovation and frequent interaction with users (e.g. housing, private services, traditional manufacturing).

The result of Pavitt's analysis was significant as it clearly showed that factors leading to successful innovation differ greatly across industries and sectors. Several innovation and patent studies (Malerba et al., (1996, 1997, 2002, 2003; Capello, 2002) have subsequently recognised the importance of sectoral patterns of innovation.

Spatial-Sectoral VC Factors. There are several accounts of the spatial and sectoral nature of venture capital. Early studies were in the geographic research tradition exploring the role of venture capital in technological innovation and regional development in the U.S. These studies (i) located the major centres of U.S. venture capital (California, Massachusetts, New York), (ii) highlighted the importance of VC networks and high degrees of intra- and inter-regional coinvestment, and pointed to (iii) unbalanced distribution of venture capital for optimal regional development (Leinbach and Armheim, 1987; Florida and Kenney, 1988; Sunley et al, 2005). The existence of well developed venture capital networks in technology-based regions was found to significantly accelerate the pace of technological innovation and economic development in those regions. In a competitive product market, new ventures financed by active investors may prey on rivals that are financed by passive investors by ''strategically over investing'' early on, resulting in long-run differences in investment, profits, and firm growth. The value of active investors can be greater in highly competitive industries as well as in industries with learning curves, economies of scope, and network effects. For such industries, a theoretical model by Inderst and Mueller (2009) predicts that start-ups with access to venture capital may dominate their industry peers in the long run. More recently, Chen et al. (2010) found that venture capital firms located in regions with high success rates of venture capital-backed investments. Venture capital firms based in locales that were venture capital centers outperformed regardless of investment stage or location. IPO occurrences were found to vary across main office investments, branch office investments, and outside investments but IPO multiples were not.

The literature provides ample support for the view that clustering factors (i.e. spatial and sectoral) of innovation and venture capital finance account for the uneven distribution of innovation.

Thus it is proposed:

Hypothesis 1: *Spatial VC investment decisions are associated with firm-level technological innovation.*

Hypothesis 2: *Spatial venture capital investment performance is associated with firm-level technological innovation.*

Hypothesis 3: *Sectoral VC investment decisions are associated with firm-level technological innovation.*

Hypothesis 4: *Sectoral venture capital investment performance is associated with firm-level technological innovation.*

DATA AND METHODOLOGY

The method of choice consists in the analysis of (private) cross-sectional archival data for U.S. VC-backed IPO (initial public offering) exit performance and related patent information spanning the 20 years from 1980-2000. The focus on U.S. data is justified by the fact that U.S. technology VC investments represent more than 50% of global VC investments in technology. Moreover whilst the origins of U.S. technology venture capital can be traced back to the 1960's little evidence of it can be found elsewhere prior to the mid 1980s. The U.S. economy is rich in technology and all technology sectors are well represented. The U.S. venture capital industry is organised in regional clusters varying in importance. Collectively these factors make the multilevel analysis of VC-backed technology firms, and firm's technological innovation and VC investment performance in particular, a unique and unequalled opportunity. The period from 1980-2000 is particularly attractive as these were buoyant times (incl. four economic business cycles) for various innovative technologies such as networking, internet and biotechnology. Moreover the duration of the study period matches the patent term of 20 years from filing date which is the time protection generally granted from patents in the U.S. Finally according to academics the USPTO is believed to be the best patent institution (Archibugi, 1992).

The sample includes 1020 VC-backed U.S. technology firms across seven different sectors which experienced an IPO exit between 1980-2000. Data are issued from two distinct worlds for their ability to test hypotheses and draw inferences: the world of patents and the world of venture capital. Whilst both of these are well established research fields on their own right few bridges exist that provide a dependable path between them. One of the main challenges of this study is to build solid bridges between the worlds of patents and venture capital.

Measures of Technological Innovation

There is a common belief that innovation is, by definition, difficult to quantify and measure. Whilst this is true for some aspects of innovation it can be argued that important process and output characteristics of *codifiable* technological innovation can be quantify and measured.

Patents (a measure of technological innovation output) and innovation surveys offered two important means of acquiring information about technological change in firms. They have advantages and disadvantages that complement other widely-used indicators such as R&D (a measure of technological innovation input), trade in high-technology products, etc. Innovation surveys can be useful but do not lend themselves to comparisons at the country or firm level. In contrast patents are found increasingly used to monitor innovations occurring within the firm and chart the direction and content of current innovative activities carried out by technology firms (Archibugi et al., 1996). The value of a growing number of firms in knowledge intensive activities is determined by the value of its IP, thus the importance of patenting and the use of patent data as a good indicator of difference in inventive activity (input and output) across firms (Griliches, 1990).

Despite its weaknesses, critics of the use of patents have not been able to provide better measures. Numerous papers have been published which support the use of patent data as an output indicator of technological innovation in economic studies (Narin et al, 1987, 1995; Brouwer and Kleinknecht, 1999; Kortum and Lerner, 1999; Acs et al, 2002).

Venture Data. Venture data consist of 2098 VC-backed US technology IPO exits in the 20 years from 1980-2000. All venture data were sourced and compiled from Thomson VentureXpert™ throughout the VC investment cycle (from selection to exit) including IPO date, total venture capital invested at IPO, IPO amount, IPO value, IPO cash-on cash multiple, and firm age at IPO. VentureXpert dataset also provides detailed company information including spatial data (city, metro area, state), sectoral data (major industry group, sectoral subgroup). The dataset, referred to as **IPO80_99**, indicates that the overall number of VC-backed technology IPO transactions increased steadily in the period from 1980-1999. VentureXpert is a proprietary database of Venture Economics, which is a division of Thomson Financial. Venture Economics receives quarterly reports on portfolio holdings from more than 1000 venture capital organizations and major institutional investors. The information includes several data points about the portfolio companies including, among other things, a designation of the type of investment, name and location of the portfolio firm, date and amount of investment and the industry in which the firm competes. Due to its richness and reliability, VentureXpert has been extensively used in venture capital research (e.g. Gompers & Lerner, 2004; Giot and Schwienbacher, 2007; Mann and Sager, 2007; Cockburn and MacGarvie, 2009). It contains the official database for the U.S. National Venture Capital Association.

Patent Data. Patent data were sourced from NBER-USPTO (Hall et al., 2001) supplemented by Thomson Delphion™ datasets to matched patent characteristics for VC-backed technology firms that have exited via an IPO transaction. The main NBER dataset extends from January 1, 1963 through December 30, 1999 (37 years), and includes all the utility patents granted during that period, totaling 2,923,922 patents; this dataset is referred as **PAT63_99**. In addition, the NBER **CONAME** file lists company names and associated assignee identifier. The patent data themselves were procured directly from the U.S. Patent Office. NBER data comprise detailed information (incl. citations) on 3 million U.S. patents granted between January 1963 and December 1999. Where the firm names shown in VentureXpert and NBER were similar but not identical, judgments were based on city/state designations and technology area.

VentureXpert-NBER Data Matching

IPO company names (2098) from VentureXpert were matched with those of the NBER-USPTO patent database. The search process relies heavily on the original USPTO's coding of assignee names. For each firm in the dataset, the Delphion database on issued U.S. patents and published applications were searched by hand using the company name, along with common abbreviations and variations in spelling of companies' names. "Weak" matches were verified by inspecting the inventor names, address information and the content of patent abstracts from Delphion. It is believed that this procedure captured all patent applications and issued patents for which a given firm was the assignee. But it is possible that some patents controlled by the firms in this sample were not captured in this search.

Since VentureXpert regional classification does not follow the standard definition of U.S. Census 2006 metropolitan statistical area (MSA) a new variable called *cometro* was constructed and all matched IPO company names were assigned a standard MSA value. MSAs with less than 10 IPO firms over the study period were dropped and included in the 'Other US' category. Data were uploaded in Stata 10, a full-featured statistical program for Windows, and all string and date variables were encoded prior to multilevel statistical treatment and analysis (Rabe-Hesketh & Skrondal, 2008). Twenty four variables were used for this study but only a subset is required to test relationships proposed in H1-H4. Figure 1 depicts model variables in relation to tested hypotheses.

(Insert Figure 1)

RESULTS

Descriptive Summary. A quick inspection of summary statistics for overall dataset shown in Table 1 reveals interesting results. During the period from 1980-2000 nearly 2 in 3 U.S. technology IPO firms (61.5% or 627 with patents and 393 without patents) engaged in patenting activity (*patent*), a proxy for technological innovation. However, when controlling for the timing of patenting of activity, a slightly different picture emerges. The pattern of patenting activity changes with fewer U.S. technology IPO firms (51%% or 521 with patents and 499 without patents) found to be engaged in pre-IPO patenting activity. Various VC investment performance dependent variables are also summarised. Average time-to-exit for technology IPOs in the 1980-2000 period was 7.4 years (*texit*). Total number of pre-IPO VC investors averaged 15 (*tovestors*) for an average of 1.5 investors for every million$ of VC invested (*investoratio*). Total amount of pre-IPO VC invested averaged $25.8 million (tovested) whilst IPO market value averaged $174.3 million over the period (*ipovalue*). The arithmetic average IPO multiple of 1020 observations over the period stood at 28.7x (*ipomul*). Standard variations however vary greatly warranting a closer graphical and statistical examination of results taking into account sectoral and regional variations.

(Insert Table 1)

Graphical Analysis. Results are depicted in Figure 2-3. Figure 2 shows U.S. IPOs by technology sectors and geography across 16 MSAs. A quick visual examination reveals substantial variation across both technology sectors and MSAs. A sectoral analysis highlights different patterns of sectoral patenting activity with the internet specific sector displaying the lowest patenting rate (24%) whilst the semiconductor/electronics and the biotechnology sectors displayed much higher patenting rates of 86% and 89%, respectively, over the study period. Similarly a regional analysis highlights different patterns of regional patenting activity with the Dallas (TX) metropolitan statistical area displaying the lowest patenting rate (35%) whilst the Portland (OR), San Diego (CA) and San Jose (CA) displayed much higher patenting rates of 92%, 84% and 79%, respectively. The aggregate regional market values of IPOs, as shown in Figure 3, indicate that San Francisco (CA) and San Jose (CA) metropolitan statistical areas and 'Other U.S.' accounted for more than 50% of the total IPO market value created over the study period. Finally the importance of signalling patenting activity prior to the IPO of technology firms is highlighted during the study period. Three years before IPO only 18% of VC-backed technology firms were engaged in patenting activity. That figure increased to 51% by the time of IPO and to 55% three years after the IPO.

(Insert Figures 2 and 3)

A pre-IPO sectoral analysis in Figure 4 indicates a slighly lower level (averaging 51%, down from 62%) of patenting activity prior to IPO. A closer look at dependent variables tovested (average total VC investment), ipovalue (IPO market value), and ipomul (IPO multiple), texit (time-to-IPO), tovestors (average number of VC investors) and investoratio (number of VC investors per million$ VC invested) also confirms significant variations across technology sectors.

(Insert Figure 4)

A pre-IPO regional overview is depicted in graphs 5-11. Figure 5 shows the pattern of pre-IPO patenting activity across all metropolitan statistical areas (MSAs) whilst Figure 6 shows how IPO exit intensity (i.e. number of regional IPOs) varies as a function of patenting activity. In Figures 7-8 average total VC investment and average IPO market value vary greatly across MSAs and appear to be consistently and significantly (negatively) influenced by pre-IPO patenting activity. Average IPO multiples in Figure 9 vary across MSAs but do not appear to be influenced patenting activity. Figure 10 however illustrates that average IPO exit velocity (i.e. average time-to-IPO in years) not only vary across MSAs and but do appear to be consistently and significantly (negatively) influenced by pre-IPO patenting activity. Similarly Figure 11 shows that VC investor intensity (i.e. average number of pre-IPO VC investors) varies across MSAs and also appears to be consistently and significantly (positively) influenced by pre-IPO patenting activity. Finally VC investor efficiency (number of VC investors per million$ VC invested) varies greatly across MSAs but does not appear to be consistently and significantly influenced by pre-IPO patenting activity.

(Insert Figures 5-11)

Adequate statistical tests and procedures are required to check the significance of all relationships between pre-IPO patenting activity and various dependent variables measuring the venture capital investment performance controlling for sectoral and regional effects.

Statistical Analysis. This study proposed to test four research hypotheses. Table 3 provides a summary. Relationships were tested by means of ANOVA analyses and multilevel mixed-effects regressions (H1-H4). Three different multilevel (ML) mixed-effects models were used for hypothesis testing, two ML regression models are fitted on regional data panels with fixed (fe) and random effects (re) and one ML regression model is fitted on sectoral data panels with fixed effects. Tables 4 and 5 summarise results from ANOVA and ML mixed-effects regressions, respectively.

(Insert Table 3)

The ANOVA Bonferroni multiple-comparison tests for 16 MSAs (P=0.0000) and 7 sectors (P=0.0000) are both significant at the 1% significance level and firm-level technological innovation of IPO firms (proxied by patenting activity) are found to be significantly influenced by both spatial factors (proxied by U.S. metropolitan statistical areas) and sectoral factors (proxied by U.S. technology sectors). Findings are consistent with previous studies by Florida & Kenney (1988) and Pavitt (1984) and Malerba et al (1996, 1997, 2002, 2003), respectively.

(Insert Table 4)

Regional panel data ML model 2 (fixed effect) produces a slightly better fit than regional panel data ML model 1 (random intercept) and it thus favoured for testing H1 and H2. H1a for VC investor intensity (*tovestors*) is accepted at the 1% significance level (P= .0000) with no sectoral effect (level-2 variable *comsec*). The *b coefficient* of 4.28 in ML model 2 means that the mean number of investors associated with technology firms with pre-IPO patenting activity (17.0) is 4.3 higher than that with technology firms without pre-IPO patenting activity (12.7). VC investor intensity (total number of VC investors) is positively associated with the patenting activity of technology firms seeking venture capital financing. H1b however is rejected and VC investor efficiency (number of VC investors/VC invested) is not significantly influenced by the patenting activity of technology firms. Sectoral effects however are significant at the 1% significance level for VC investor efficiency. H2a, IPO exit intensity (number of IPOs) is not significantly associated with pre-IPO patenting activity (1:1 ratio). 521 IPOs with pre-IPO patenting activity against 499 IPOs with pre-IPO patenting activity were recorded over the study period. ML model 2 for total VC invested (*tovested*) and IPO value (*ipovalue*) are significantly (negatively) associated with patenting activity at the 1% significance level (P=0.000), respectively. Negative *b* coefficients of -6.7 and -47.2 mean that total VC invested and IPO value are lower by $6.7m and $47.2m, respectively, where technology IPO firms were engaged in patenting activity. However ML model 2 for IPO multiple (*ipomul*) rejects H2d with no sectoral effect (level-2 variable *comsec*). ML model 2 for IPO exit velocity (*texit*) support the acceptance of H2e at the 5% significance level (P= .0358) with a weak sectoral effect at 10% significance level. The *b coefficient* of 1.2 means that the mean time-to-IPO is 1.2 years longer for technology firms with pre-IPO patenting activity (8.0) than that for technology firms without pre-IPO patenting activity (6.8). Contrary to resource-based view theory results from regional panel data analyses point out to a strong negative relationship between pre-IPO patents, a unique and important strategic resource esp. for technology firms, and venture capital investment performance as measured by total VC investment (H2b), IPO value (H2c) and IPO exit velocity (H2e). However H2d (*ipomul*) is rejected as not significantly influenced by the pre-IPO patenting activity of technology firms.

Moreover sectoral effects (level-2 variable *comsec*) also have a significant effect on total VC investment, IPO value and time-to-IPO.

(Insert Table 5)

Sectoral panel data ML model 3 (fixed effects) for VC investor intensity (*tovestors*) support the acceptance of H3a at the 1% significance level (P= .0052) with a weak regional effect (level-2 variable *cometro*) at the 10% significance level. Sectoral panel data ML model 3 shows a *b coefficient* of 4.1 meaning that the mean number of investors associated with technology firms with pre-IPO patenting activity is 4.1 higher than that with technology firms without pre-IPO patenting activity. VC investor intensity (total number of VC investors) is positively associated with the patenting activity of technology firms seeking venture capital financing. H3b is accepted at the 1% significance level as VC investor efficiency (number of VC investors/VC invested) is found to be positively influenced by the patenting activity of technology firms. Regional effects (level-2 variable *cometro*) for VC investor efficiency and total VC investment are found to be significant at the 1% and 5% significance level, respectively. .

DISCUSSION AND CONCLUSION

Resource-based view and knowledge-based view theories argue that technological innovation is a strategic resource of the firm that can provide competitive advantage and produce superior performance. However this regional study of U.S. VC-backed technology IPOs provides new evidence that, for young technology firms, a focus on patenting technological innovation may be misplaced. Results show that, irrespective of geography, pre-IPO patenting activity is negatively associated with venture capital investment performance as measured by total VC investment, IPO value and IPO exit velocity. In contrast with Mann and Sager (2007) who found that start-ups in the software sector with a larger numbers of patent applications were more likely to exit successfully through an IPO a large majority (68%) of IPO firms in the software sector were found not to be engaged in patenting activity at the time of the IPO. These results appear to be inconsistent with resource-based view theory. Possible explanations can be found in the venture capital cycle.

Stuck and Weingarten (2005) postulated that the venture capital cycle may be a reason why innovation may get short-circuited. Venture capital investment is characterised by a life cycle which is usually limited by the term of the VC fund (typ. 10 years). Complex, codified technological innovations, in the form of patents, arguably require more time and more financial resources to fully develop (i.e. productise) and exploit than tacit knowledge or other types of knowledge. In VC terms, additional time and money are both investment deterrents which have adverse impacts on VC investment performance. Moreover patents, by their very nature, provide owners with the right to exclude others from making, using, selling the patented invention for the term of the patent which is usually 20 years from the filing date. For venture capitalists which must realise portfolio investments within less than 10 years, be via an IPO or trade sale exit (or a write-off), patents may provide a false sense of comfort resulting in poorer investment performance. Possibly the fact that only half of IPO firms were engaged in patenting activity is indicative of the difficult challenge faced by VC-backed technology firms pursuing technological innovation. Moreover the few firms that make it through the venture capital cycle take longer to exit and achieve a significantly lower IPO value. However the acceleration, a few years prior to IPO, of technology IPO firms engaged in patenting activity is revealing of the importance for technology firms to signal their ability to innovate. In such circumstances that is, within the parameters of the venture capital cycle, one might conclude that patents are not a strategic resource for time-bound VC-backed technology firms that can provide them with competitive advantage and produce superior performance. Rather patents should be primarily seen as signals of capacity to innovate.

This research examined the influence of spatial and sectoral factors which have been found to be meaningful predictors in theories (i.e. regional growth, industrial, cluster and evolutionary theories) explaining the uneven geography of technological innovation. Regional analyses of technology IPO firms showed large variations in regional patenting activity across the U.S. with the highest patenting rates recorded on the U.S. West Coast in MSAs situated in California (San Jose, San Diego) and Oregon (Portland). *Patenting activity* was shown to vary significantly across sectors and regions (as shown in Bonferroni ANOVA analyses). But why were U.S. VC-backed technology firms, irrespective of geography, compelled to engage in the patenting of technological innovation? The answer to this question is revealed by research findings which suggest that, for U.S. technology start-ups, being engaged in patenting activity influenced investment decisions by venture capitalists and increased the likelihood of securing funding from VC investors (irrespective of geography and sector). Technology firms engaged in patenting activity at the time of IPO had *more VC investors* than firms which were not. These findings are consistent with prior research on VC selection (Caselli et al, 2006; Clarysse et al, 2004).

Results also show that spatial factors influence the investment performance of VC-backed technology firms. Dependent variables *total VC invested, IPO value* and *time-to-IPO* were shown to vary significantly across regions. Findings highlight the importance of regional factors of innovation and venture capital investment and are consistent with previous studies (Chen et al, 2010; Sunley et al, 2005; Florida & Kenney, 1988; Leinbach & Armhein, 1987). The importance of spatial clusters is also consistent with Porter (1998) who argued that clusters, defined as geographic concentrations of interconnected companies and institutions in a particular field, were a striking feature of virtually every U.S. metropolitan economy. Thus on one hand patenting activity increases the likelihood of VC funding (more VC investors) but on the other hand it appears to adversely impact VC investment performance (i.e. lower total VC invested, lower IPO value, longer time-to-exit). The apparent paradox is best understood in the evidence provided by previous research showing that the value of patenting resides primarily in the signalling effect of patents (Hsu and Ziedonis, 2007).

Patents provide a vehicle for overcoming early-stage disclosure issues in the market for new ideas and alleviate problems of information asymmetries. Contract theory, and in particular information asymmetry, offers an alternative explanation for results. In contract theory, information asymmetry deals with the study of decisions in transactions where one party has more or better information than the other. Akerlof (1970) modelled the interplay of signaling and screening to alleviate the problem of information asymmetry. Taking Akerlof's argument for technology firms with patents, the average value of these firms may go down, even for those of perfectly good quality. Because of information asymmetry, unscrupulous entrepreneurs (or inventors) can trick technological innovation and defraud investors. As a result IPO investors, who are not technology experts, may not be willing to risk getting ripped off. IPO investors may edge their bets against technology firms with patents and may not value them as much as they should. Technology firms engaged in the patenting of inventions are generally associated with greater information asymmetry between entrepreneurs (or inventors) and venture capitalists. This helps explain why a greater number of VC investors (e.g. specialist technology VC investors) were found to be interested in such ventures as VCs usually expect to add value to investee companies. These ventures carry higher levels of uncertainty associated with the underlying technology. This may explain why fewer than 50% of technology firms which managed to exit via an IPO were engaged in patenting and when they did they took longer to exit and resulted in lower IPO values. VC investors must exert caution about the fallacies of building viable businesses based on patents alone. Surely the 'business idea' referred to by Kaplan et al (2009) goes beyond mere patents.

This study provides new insights by positioning patents as quality signals available to entrepreneurs and by estimating their effects across various stages of the venture life cycle. Findings reveal an important interplay between the patent signalling and investment decisions by venture capitalists in young technology firms. Findings also reveal that once the signalling value of patents has been realised (influencing VC investment decision) patents, rather than the 'business idea', risk to become the focal point of the technology venture resulting in lower venture capital investment performance (i.e. longer time-to-IPO, lower IPO value). The patenting of technological innovation can be a double-edge sword. Future work is needed to examine broader characteristics of patenting and its temporal effects on venture capital investment performance and test the generalisation of these results to other exit routes i.e. trade sale before definitive conclusions can be drawn and useful guidance provided.

Results and conclusions from this research can have important implications for academic research, venture capital practice and regional innovation policy:

1. Results may contribute to theory development and improve the knowledge and understanding of how the geography of technological innovation influence to the performance and success of technology start-ups and VC firms alike. Research can hopefully open up new avenues and encourage further academic research on regional technological innovation and its impact on VC funding decisions, investment performance and company valuations.
2. Research findings can provide new insights to VC practitioners seeking to improve their screening and selection process for regional venture investment opportunities. This in turn can reduce reliance upon anecdotal evidence and subjective assessment based on personal preferences or experiences.
3. Research findings can also have far reaching implications for public innovation policy funnelling large sums of money through various innovation initiatives to help fund regional technological innovation irrespective of its ability to produce expected economic results.

However this study has several limitations and further work is required:

1. Whilst this research focuses on patented inventions many technological innovations are not patented. New research methods are needed to collect reliable data on different types of innovation relevant to young technology firms.
2. All patents are not created equal. Patent characteristics such as relative importance needs be studied in more detail if one aims to evaluate their influence on venture capital investment performance.
3. The net benefits of alternative measures of technological innovation at different stages in the venture capital cycle represent an understudied yet promising avenue for further study.

4. Temporal aspects of technological innovation are neglected. One might convincingly argue that sooner technological innovation takes place the greater its impact might be on venture capital investment performance. The timing of patents may also influence investment decisions from venture capitalists. These temporal effects, being nested within regions and sectors, means that more sophisticated controls for collinearity and endogeneity may call for the use of advanced multilevel (i.e. 3-level) mixed-effects modelling techniques.
5. M&A exits are excluded from this study. Although the IPO exit is generally recognised by VCs as the ultimate measure of success (and the most profitable one) it is, by no means, the only exit route. In fact, U.S. technology firms are twice as likely to exit via an M&A than via an IPO (Metrick, 2007).

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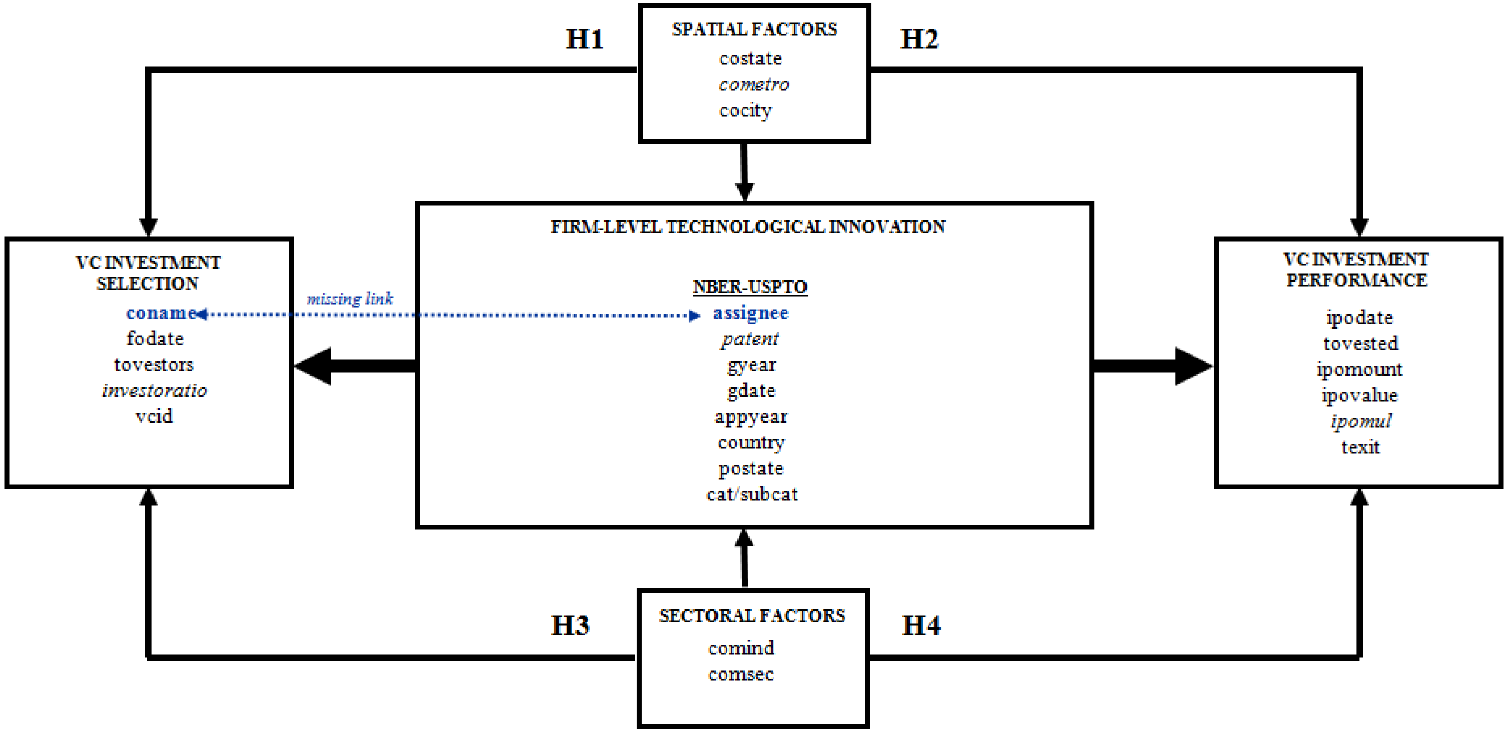
FIGURE 1 HYPOTHESES AND MODEL VARIABLES



Note: Constructed variables are shown in italics.

Dependent Variables

tovested:	Total (known) Venture Capital Amount Invested in million$
ipovalue:	IPO Post Offer Value in million$
ipomul:	IPO Cash Multiple (=ipovalue/tovested)
texit:	Time Elapsed from Inception to IPO in years
tovestors:	Total Number of Firm VC Investors
investoratio:	Ratio of Number of VC Investors/ million$ VC Invested (=tovestors/tovested)

Independent Variables

patent:	Dichotomous variable indicating presence of patenting activity (0= without patents, 1= with patents)

Control Variables

cometro:	Company Metropolitan Statistical Area (MSA)
comsec:	Company Technology Sector
ipodate:	IPO Date
appyear:	Patent Application Year
gyear:	Patent Grant Year

TABLE 1 SUMMARY STATISTICS

Variable |	Obs	Mean	Std. Dev.	Min	Max
coname |	1020	510.5	294.5929	1	1020
fodate |	1020	9449.116	3358.967	-36158	14365
cocity |	1020	1213.058	103.3706	1021	1385
costate |	1020	1400.298	12.45141	1386	1425
cometro |	1020	1439.679	6.068158	1426	1448
comsec |	1020	1452.193	1.948037	1449	1455
comind |	1020	1456.319	.4661728	1456	1457
ipodate |	1020	12137.39	1985.092	7373	14595
texit |	1020	7.363529	7.337321	.2	130.4
tovestors |	1020	14.91373	15.57546	1	145
tovested |	1020	25.78706	45.5646	.1	710
ipomount |	1020	34.49804	31.09944	.5	284.1
ipovalue |	1020	174.2873	257.1884	1.2	2965.2
ipomul |	1020	28.74951	126.9168	.1	2498
investoratio |	1020	1.530331	2.375224	.0057	35
patent |	1020	.6147059	.4869035	0	1

FIGURE 2 GRAPHICAL OVERVIEW

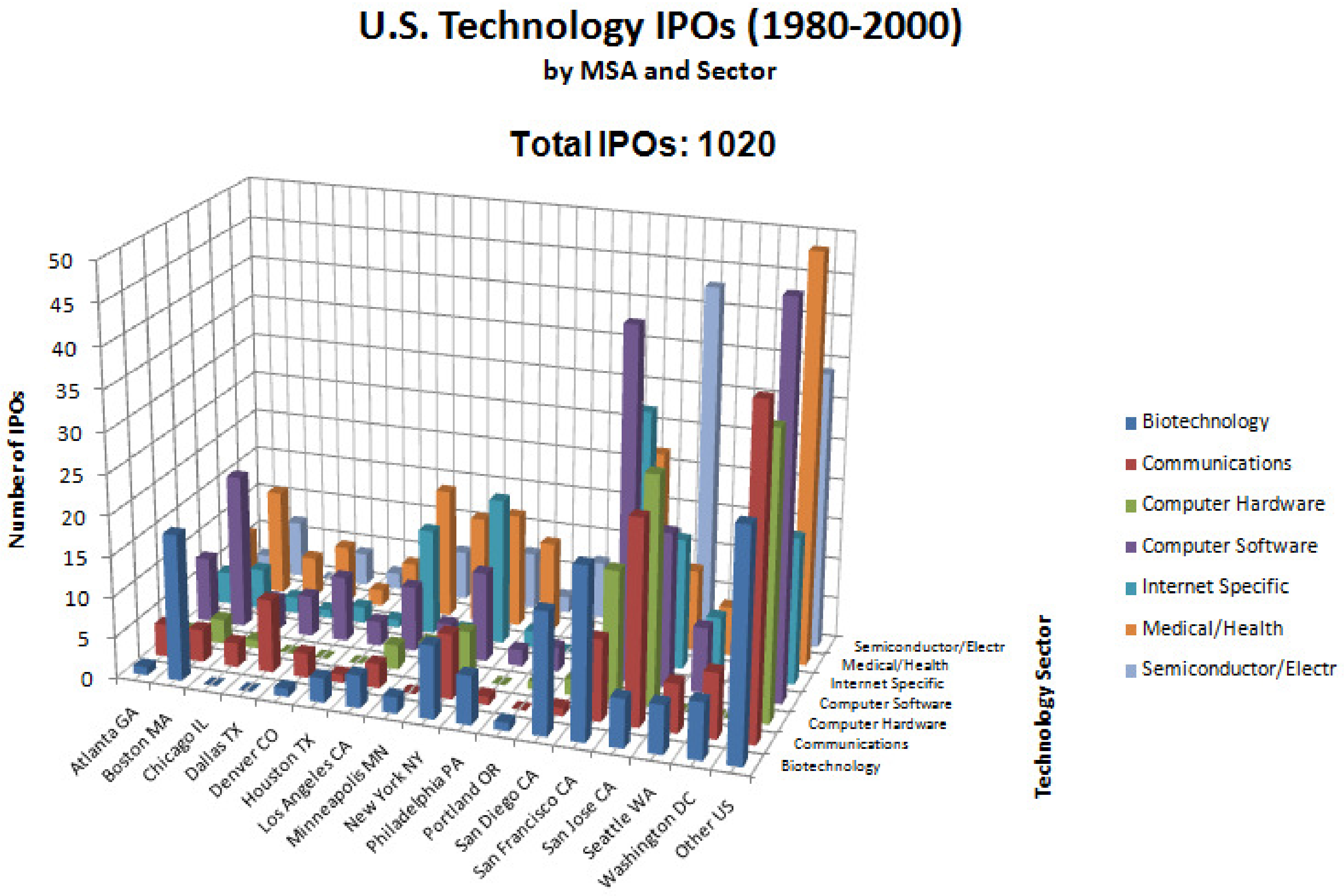


FIGURE 3 REGIONAL OVERVIEW

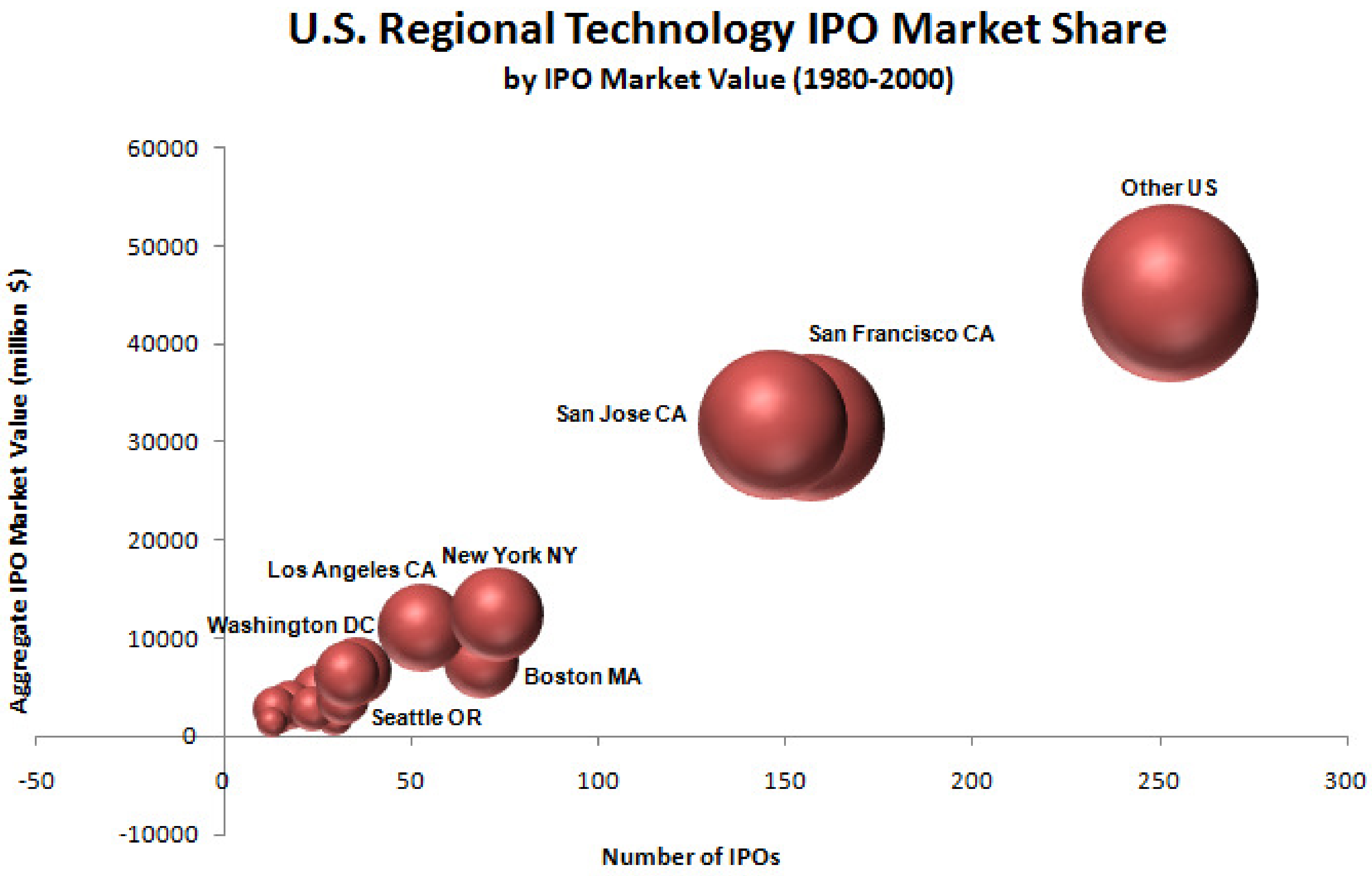


FIGURE 4 PRE-IPO SECTORAL ANALYSIS

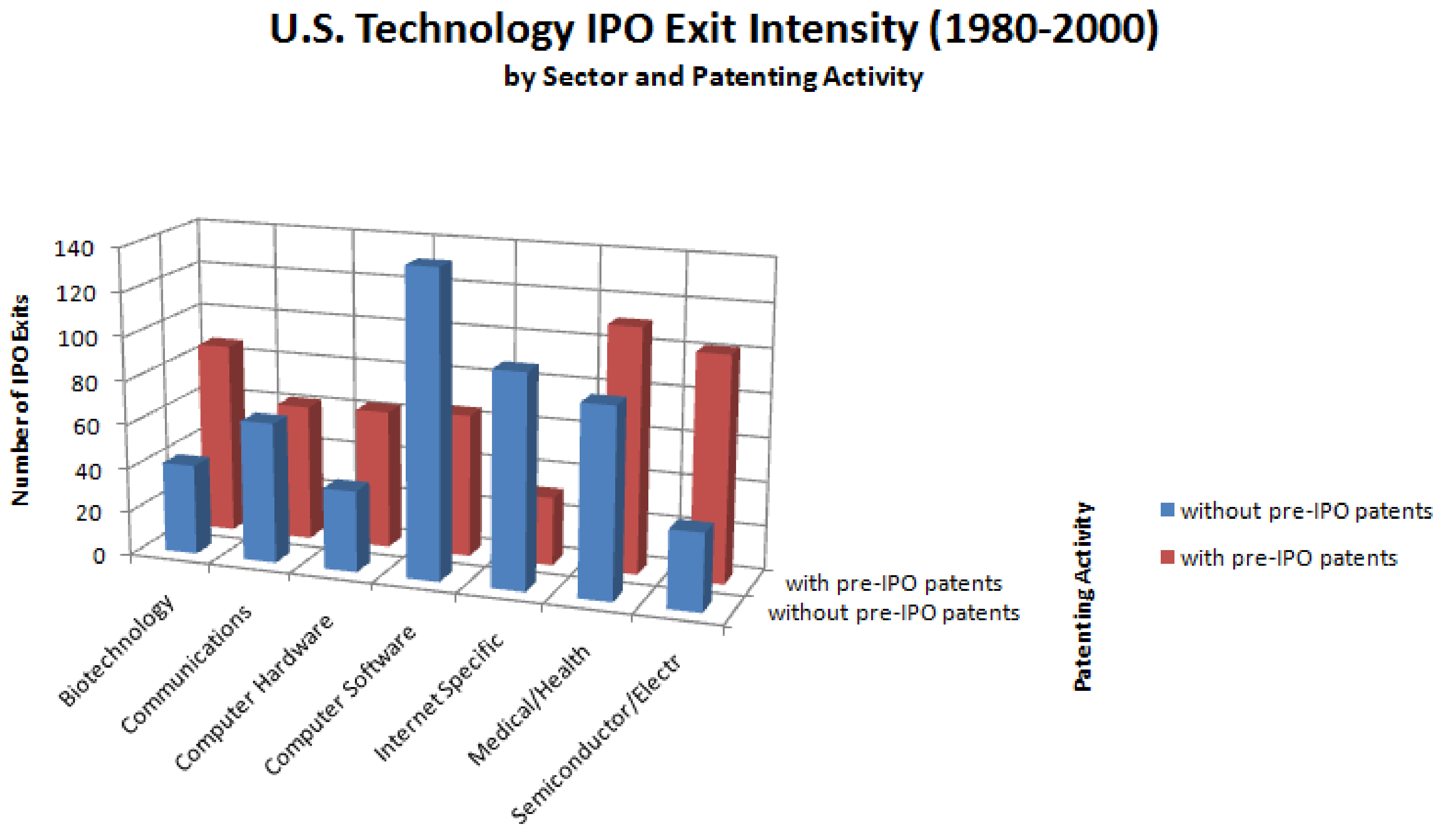


FIGURE 5 PRE-IPO REGIONAL ANALYSIS

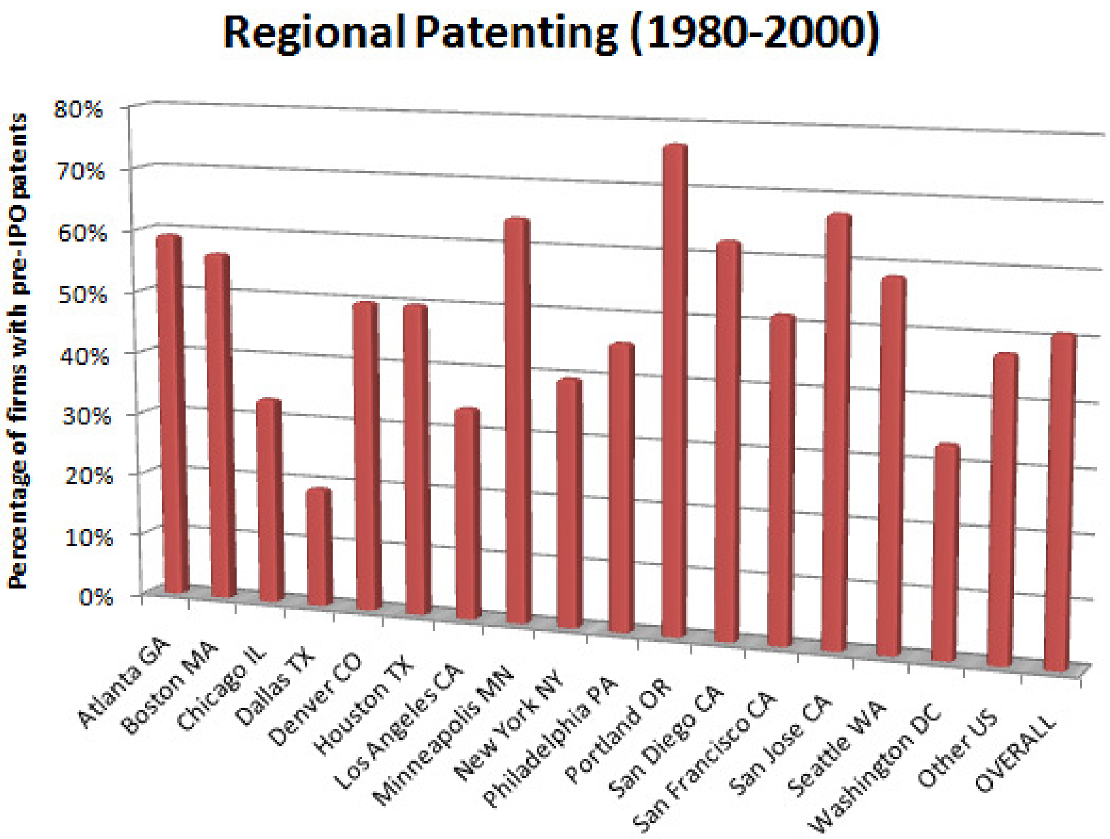


FIGURE 6   PRE-IPO REGIONAL ANALYSIS

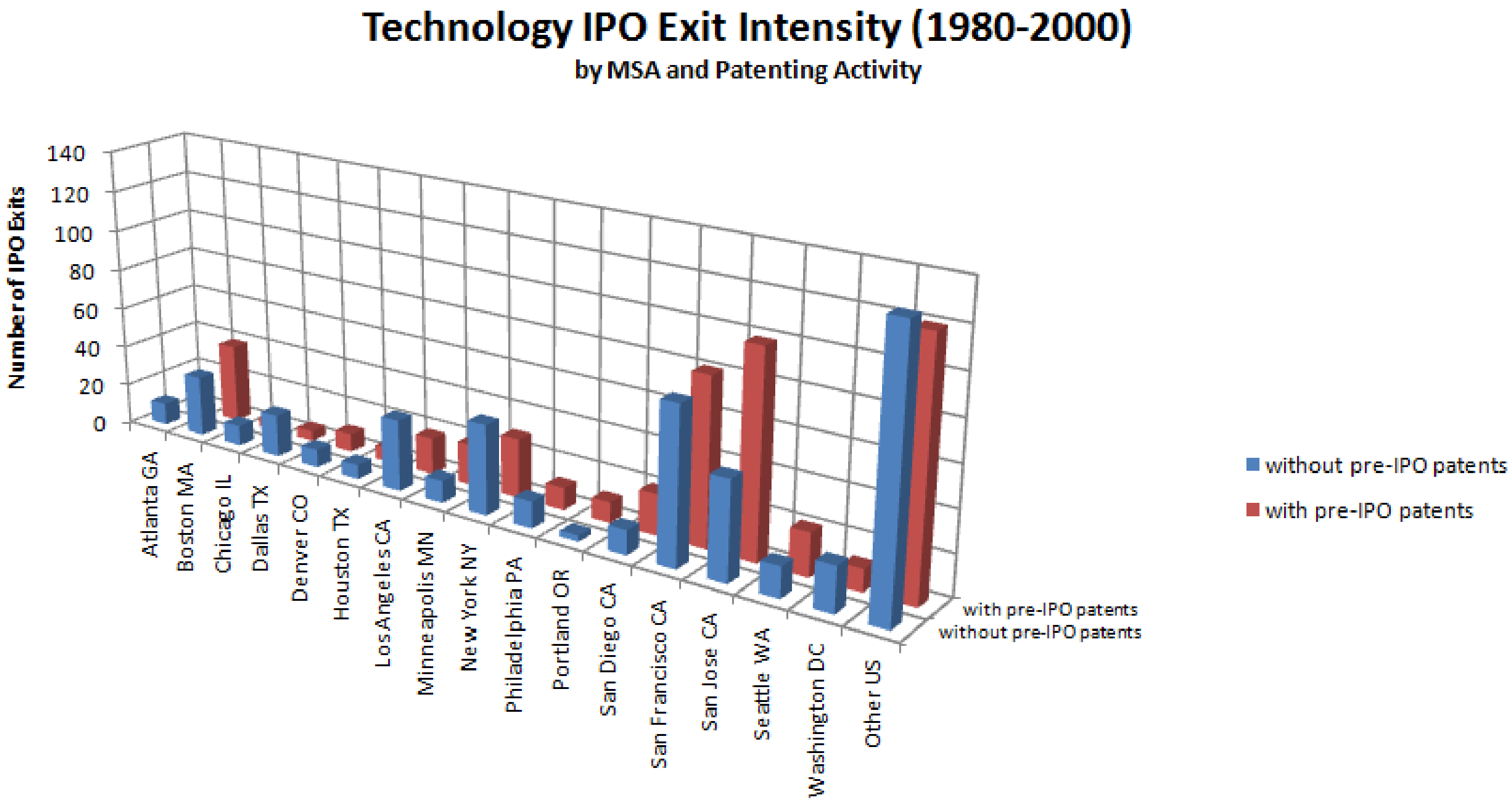


FIGURE 7 PRE-IPO REGIONAL ANALYSIS

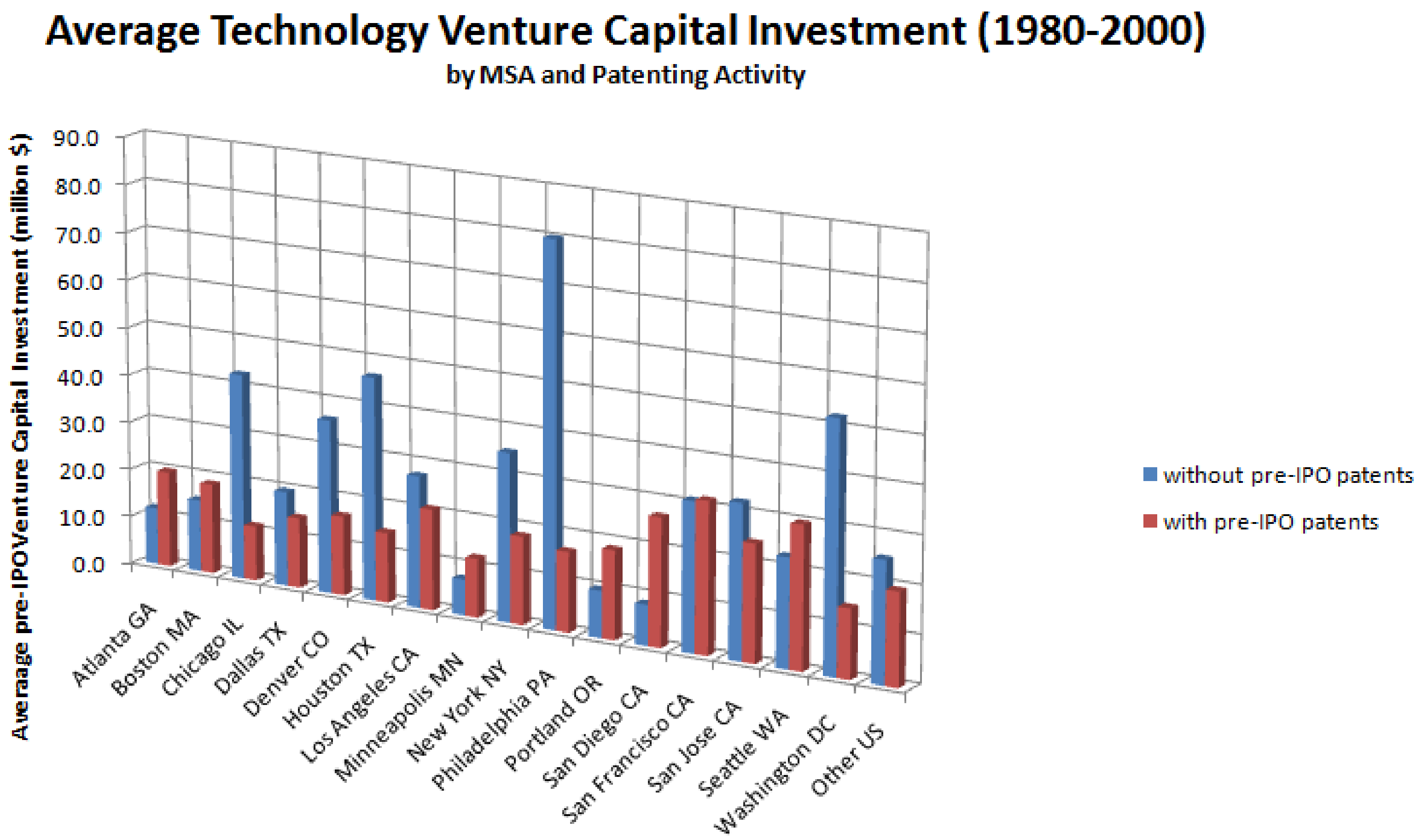


FIGURE 8 PRE-IPO REGIONAL ANALYSIS

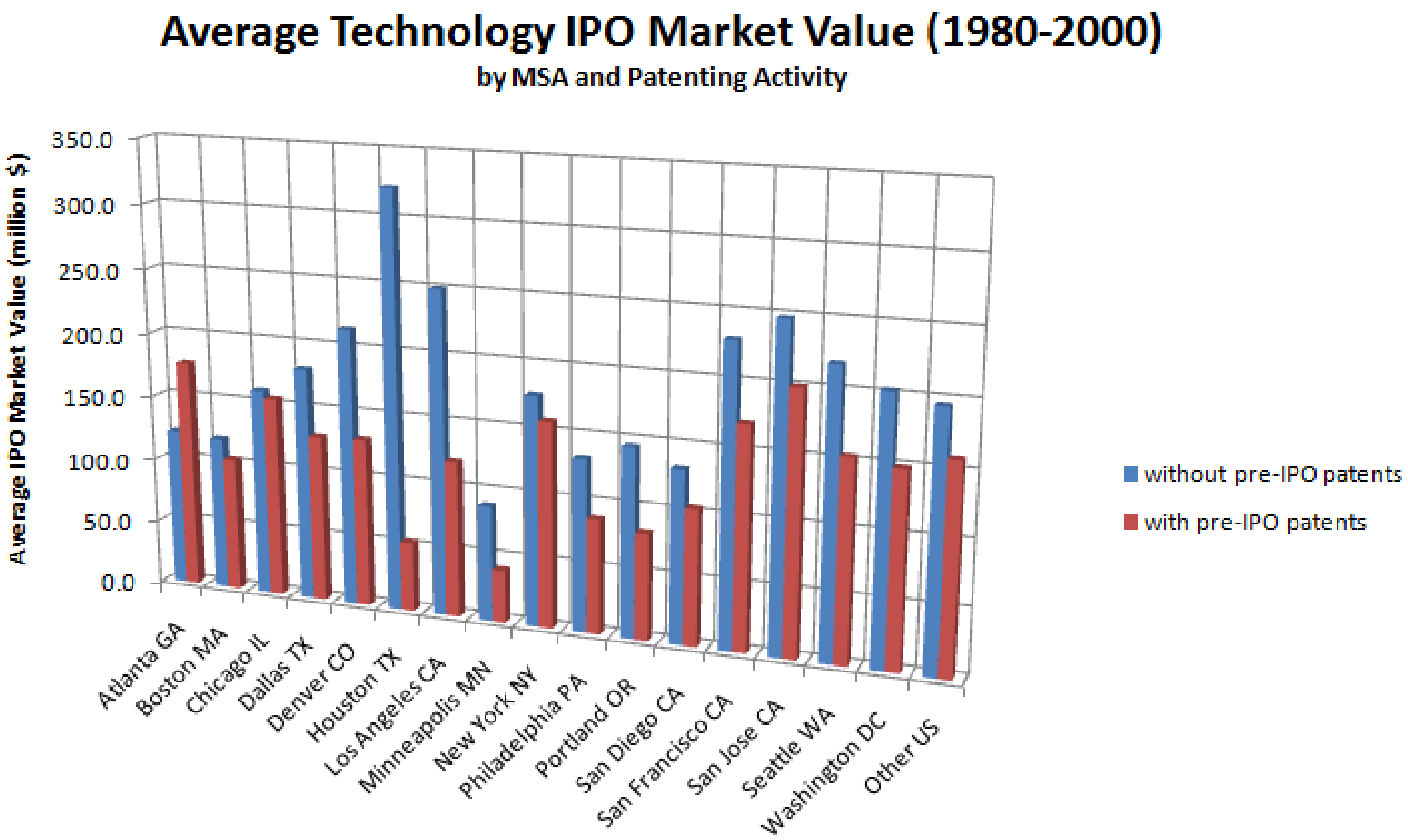


FIGURE 9 PRE-IPO REGIONAL ANALYSIS

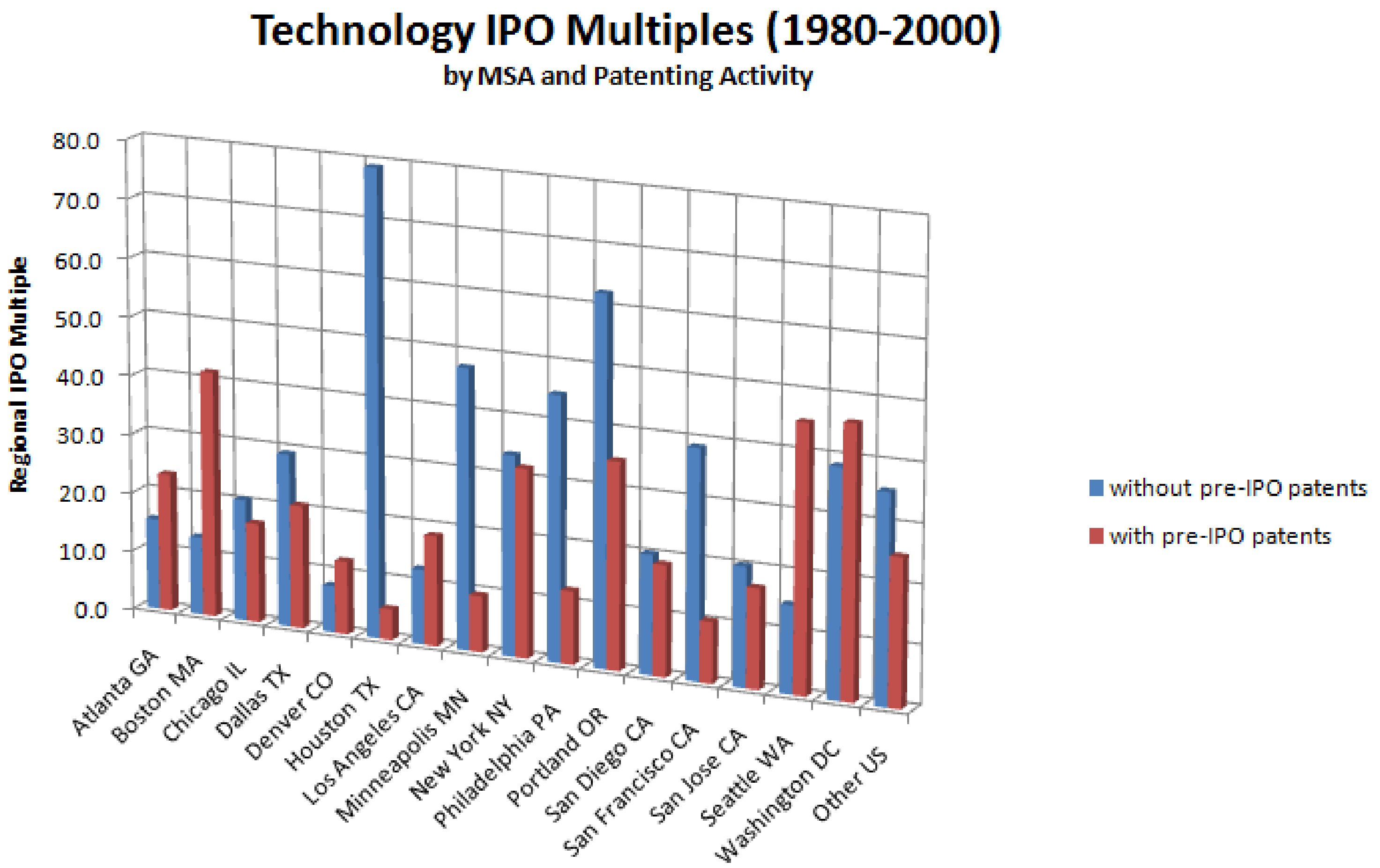


FIGURE 10 PRE-IPO REGIONAL ANALYSIS

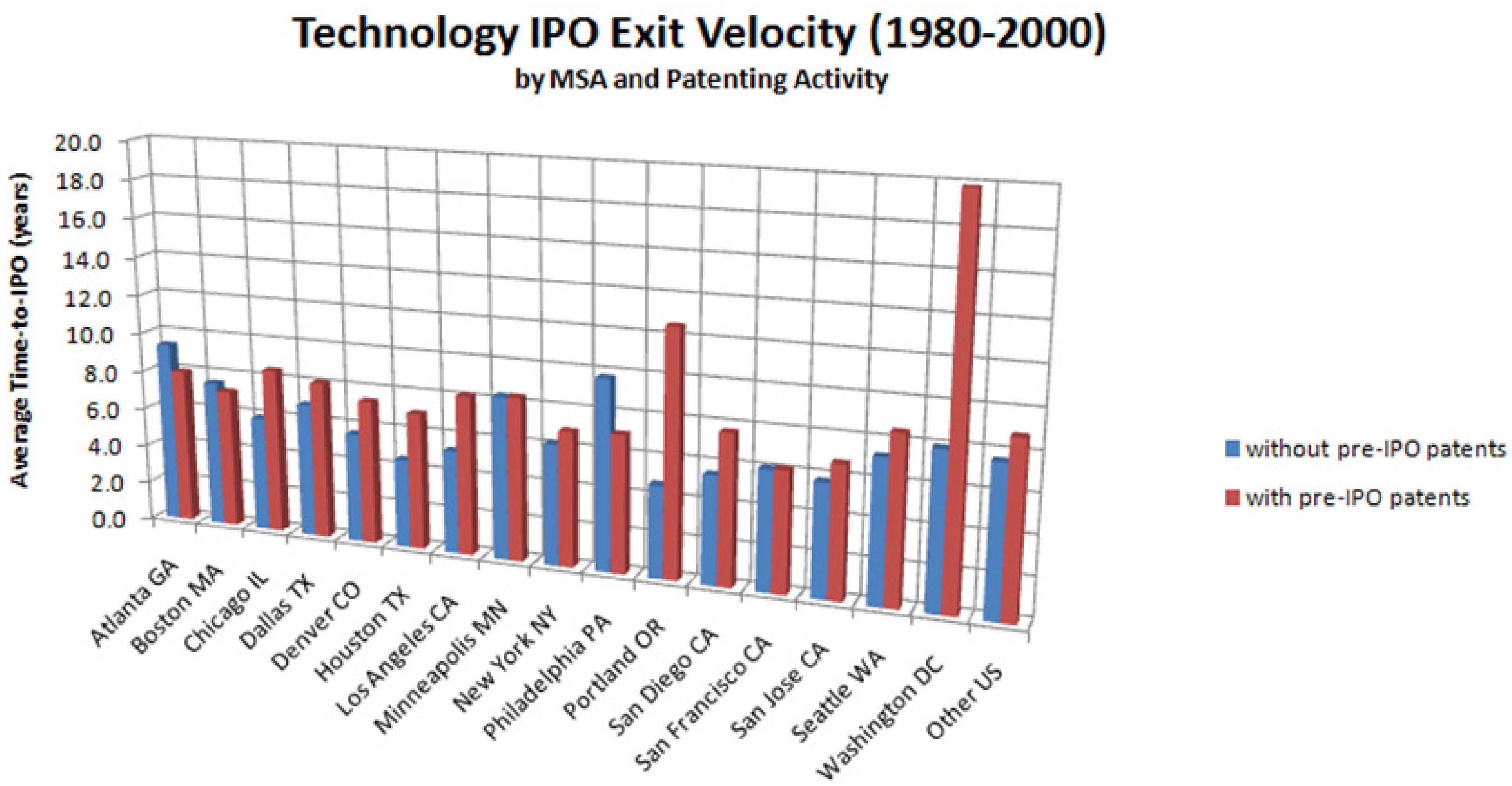


FIGURE 11 PRE-IPO REGIONAL ANALYSIS

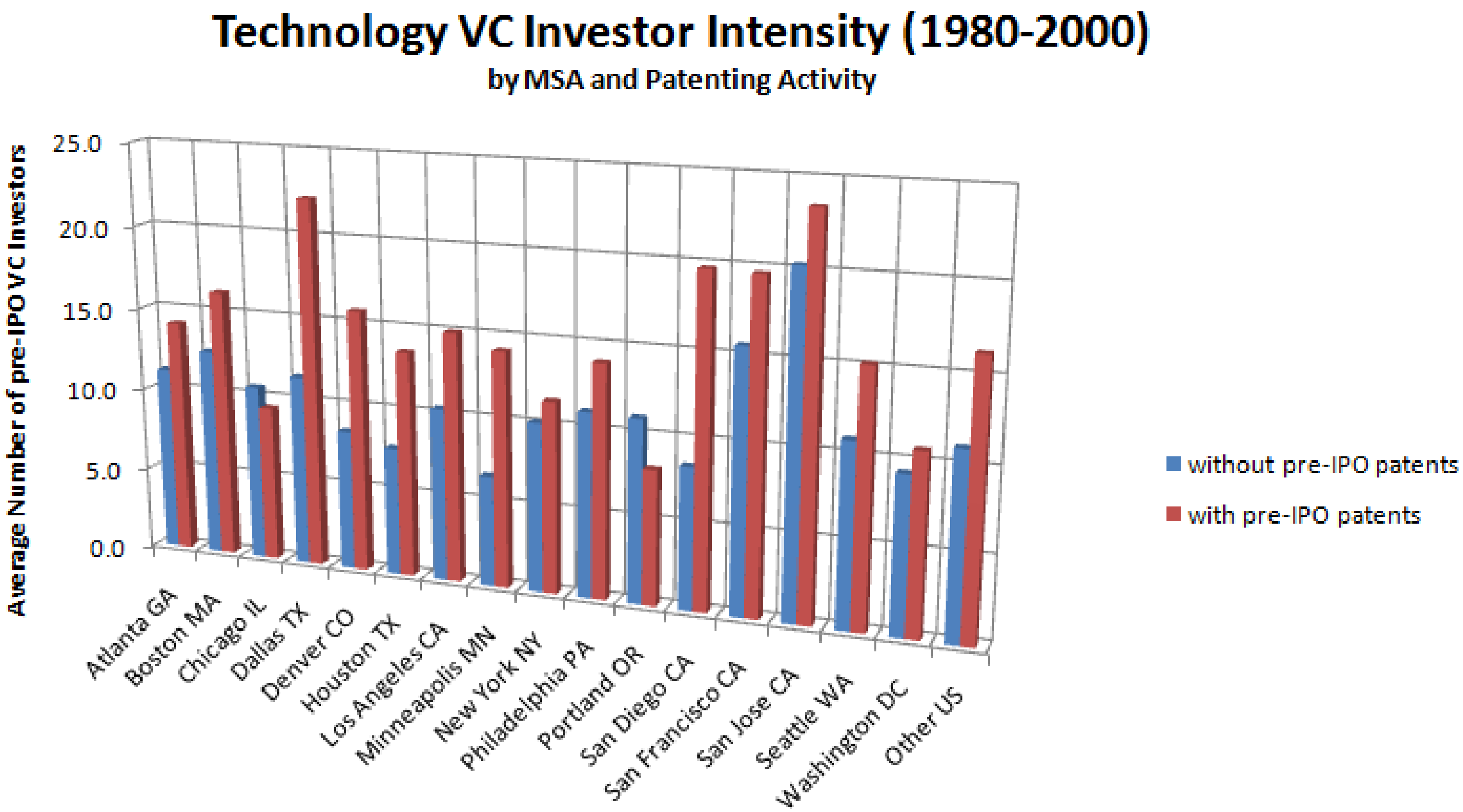


TABLE 3 TESTED HYPOTHESES

Hypothesis 1:	*Spatial VC investment decisions are associated with firm-level technological innovation:* *a. VC Investor Intensity; b. VC Investor Efficiency*
Hypothesis 2:	*Spatial venture capital investment performance is associated with firm-level technological innovation:* *a. IPO Exit Intensity; b. VC Investment; c. IPO Value; d. IPO Multiple, e. Time-to-IPO*
Hypothesis 3:	*Sectoral VC investment decisions are associated with firm-level technological innovation:* *a. VC Investor Intensity; b. VC Investor Efficiency*
Hypothesis 4:	*Sectoral venture capital investment performance is associated with firm-level technological innovation:* *a. IPO Exit Intensity; b. VC Investment; c. IPO Value; d. IPO Multiple, e. Time-to-IPO*

TABLE 4 ANOVA ANALYSES

ANOVA	tovested-patent		ipovalue-patent		ipomul-patent		texit-patent		tovestors-patent		investoratio-patent	
	SS	MS	SS	MS	SS	MS	SS	MS	SS	MS	SS	MS
Between groups	12858.51	12858.51	551254.53	551254.53	43505.98	43505.98	287.29	287.29	6691.36	6691.36	1.66	1.66
Within groups	2102720.38	2065.54	66851368.80	65669.32	16370428.80	16080.97	54571.87	53.61	240513.05	236.26	5747.22	5.65
Total	2115578.89	2076.13	67402623.30	66145.85	16413934.70	16107.88	54859.16	53.84	247204.41	242.60	5748.88	5.64
Prob > F Analysis of Variance	0.0128**		0.0038***		-		0.0208**		0.0000***		-	
Prob > chi2 Bartlett's test for equal variances	0.000***		0.000***		0.000***		0.000***		0.000***		0.015**	
Prob (T > t) or Prob (T < t) Two-sample t test with unequal variances	0.0071***		0.002***		0.0528*		0.0100***		0.0000***		-	

****** 1% significance level, ** 5% significance level, * 10% significance level***

BONFERRONI ANOVA	patent-cometro		patent-comsec	
	SS	MS	SS	MS
Between groups	13.33	0.83	29.92	4.99
Within groups	241.55	0.24	224.97	0.22
Total	254.88	0.25	254.88	0.25
Prob > F Analysis of Variance	0.0000***		0.0000***	
Prob > chi2 Bartlett's test for equal variances	1.000		0.444	

****** 1% significance level, ** 5% significance level, * 10% significance level***

TABLE 5 MULTILEVEL MIXED-EFFECTS REGRESSIONS

Regional Data Panels	tovested		ipovalue		ipomul		texit		tovestors		investoratio	
	Model 1 (re)	Model 2 (fe)	Model 1 (re)	Model 2 (fe)	Model 1 (re)	Model 2 (fe)	Model 1 (re)	Model 2 (fe)	Model 1 (re)	Model 2 (fe)	Model 1 (re)	Model 2 (fe)
R-sq within **R-sq** between **R-sq** overall	0.0125 0.1935 0.0137	0.0125 0.1929 0.0137	0.0119 0.2036 0.0115	0.0119 0.2029 0.0115	0.0019 0.0706 0.0028	0.0019 0.0691 0.0028	0.0139 0.0199 0.0109	0.0139 0.0197 0.0109	0.0191 0.0786 0.0271	0.0191 0.0774 0.0271	0.0069 0.1268 0.0082	0.0069 0.1172 0.0081
Prob > chi2 (re), F (fe)	0.0036***	0.0002***	0.0072***	0.0001***	-	-	0.0177**	0.0358**	0.000***	0.0000***	0.0323**	0.0116**
patent *(b coefficient)*	-7.10**	-6.70**	-46.20***	-47.25***	-	-	1.17**	1.20**	4.60***	4.28***	-	-
comsec *(c coefficient)*	-2.06***	-2.00***	-7.60**	-8.13**	-	-	0.31***	0.33*	-	-	0.11***	0.10***

****** 1% significance level, ** 5% significance level, * 10% significance level***

Sectoral Data Panels	tovested	ipovalue	ipomul	texit	tovestors	investoratio
	Model 3 (fixed-effects)	Model 3 (fixed-effects)	Model 3 (fixed-effects)	Model 3 (fixed-effects)	Model 3 (fixed-effects)	Model 3 (fixed-effects)
R-sq within **R-sq** between **R-sq** overall	0.0085 0.2146 0.0122	0.0038 0.0097 0.0047	0.0023 0.1475 0.0036	0.0032 0.1659 0.0053	0.0282 0.8195 0.0401	0.0079 0.2364 0.0042
Prob > F	0.0763*	-	-	0.0607**	0.0052***	0.0100***
patent *(b coefficient)*	-	-	-	0.87**	4.11***	-0.18**
cometro *(c coefficient)*	0.61**	-	-	-	0.26*	-0.03***

****** 1% significance level, ** 5% significance level, * 10% significance level***